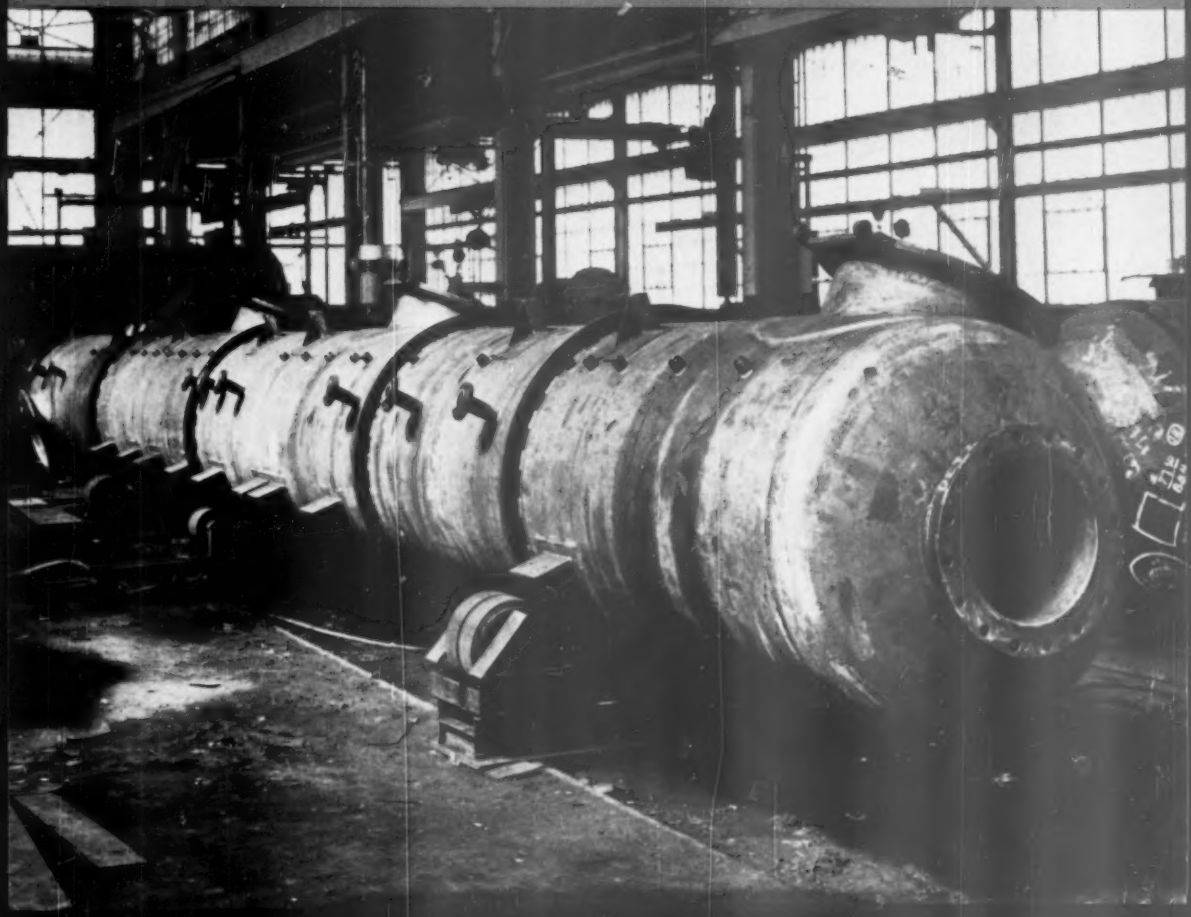
The NOVEMBER, 1950

WELDING JOURNAL

Official Publication of the American Welding Society



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cover: A welded stainless steel fractionating column used for distillation of tar and tar acids. This column is 48 in. O. D. x 49 ft. 10 in. long, and weighs 22,000 lb. *Courtesy Colonial Iron Works Co.*

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For the Production Engineer's Notebook—

Ideas for Welded Design

Product engineers, even the geniuses among them, find that the formula, "1% inspiration, 99% perspiration,"* pretty regularly applies.

Perspiration in design is brought about by the inevitable conflict between operating function—how well the part will do its job—and such other important factors as sales appeal, serviceability, and manufacturing methods.

What we are all striving for is to apply welding most economically. We in LINDE stand ready to help the product engineer in the applications of welding methods wherever we can. Sometimes economies in production come from a substitution of welding for more expensive methods, but often just a small change in design or practice reduces the cost of present welding operations.

Pointers on welded design leading to production economies.

Use the process that gives the greatest total economy.

Design for down-hand welding where possible. But locate welds so as to minimize handling.

Mechanize welding. Weld as many joints simultaneously as possible.

Make minimum dimension changes when making different sized models.

Reduce the number of parts. But sometimes it is better to increase the number of parts and cut rejects in intricate castings or formings by welding together simple forms.

Use standard shapes and easily formed sections.

Pointers on welding processes leading to production economies.

UNIONMELT welding: high speed process for deep-penetrated welds—minimum cleaning and finishing—no spatter, sparks, or smoke—usually mechanized—will make butt, tee, and lap fillets, plug, and molded welds. Used for most ferrous and many non-ferrous metals. Ask LINDE for booklet F-6077.

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* "Genius is 1% inspiration and 99% perspiration," credited in GOLDEN BOOK, April, 1931, to a newspaper interview with Thomas A. Edison.

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The WELDING JOURNAL

volume 29 November 1950 number 11

Design and Installation of Large-Diameter Long-Span Welded Pipe

The need for longer spans of self-supporting pipe has resulted in the use of ring girders. Rigid ring girders at points of support prevent distortion throughout the length of the span

by H. Jackson

LONG-span pipe was first used many years ago in Europe. Like many developments originating in Europe it seemed to progress to a certain point then remain stationary until further developed by this country.

Its use in the U. S. has been confined to perhaps the last 20 years. I refer of course to so-called self-supporting ring-girder type of long-span pipes.

Most of the earlier designs of long-span pipe were supported by cradles on each end of the pipe or cradles between the spans. This type of construction limited the span to comparatively short distances.

H. Jackson is Plant Superintendent, Thompson Pipe & Steel Co., Denver, Colo.

Presented at the Thirty-first Annual Meeting, A.W.S., Chicago, Ill., week of Oct. 22, 1950.

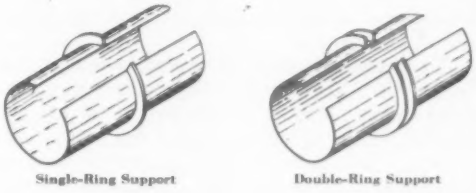


Figure 2

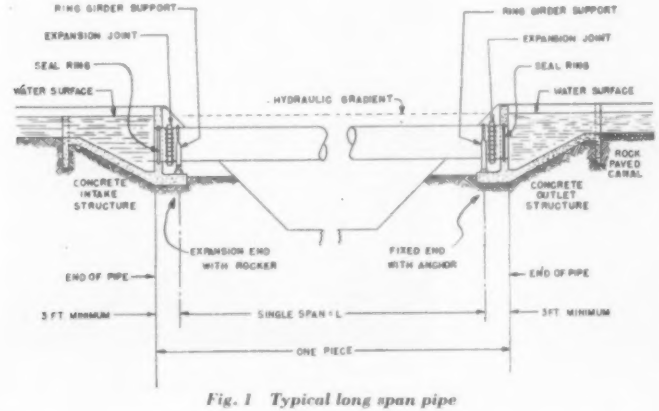
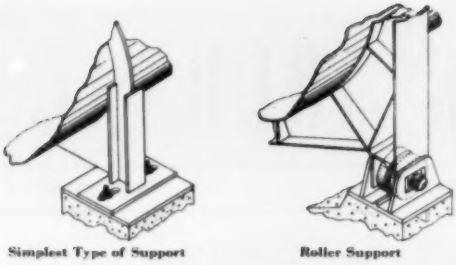


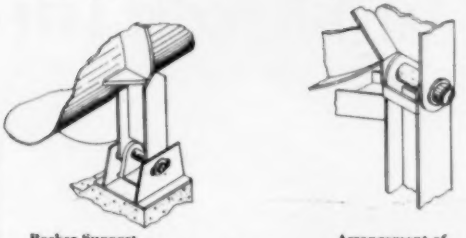
Fig. 1 Typical long span pipe

In recent years the need for longer spans of self-supporting pipe has resulted in the use of ring girders believed to have been introduced into the United States in 1930 by Herman Schorer. Rigid ring girders at points of support prevent distortion throughout the length of the span.

When bending and lateral strength are considered, the cylindrical section makes a good beam. Fig. 1 shows one type of a long-span pipe. Its basic parts are a shell, ring girders, expansion joints, and supports. Please note this drawing is schematic. A concrete transition similar to this would not be very efficient.



Simplest Type of Support — Roller Support



Rocker Support — Arrangement of Pin-End Bents

Figure 3

Fig. 2 shows four types of stiffner rings. A modification of one of these is usually used to attach the support legs shown on Fig. 3.

The longest span of pipe in the world is located near Cody, Wyo. The pipe is 123 in. diameter with a center span of 150 ft. It was designed by and built for the U. S. Bureau of Reclamation. I believe our Company still holds title to "runner up" on a 84-in. diameter line, Fig. 4, with spans of 126 ft. installed at Toston, Mont. across the Missouri River. As you may know earthquakes are frequently experienced at Helena a few miles from Toston. This long-span steel pipe is indicative of the confidence held by many engineers after investigating other types of structures.

Fig. 4 Toston long span pipe

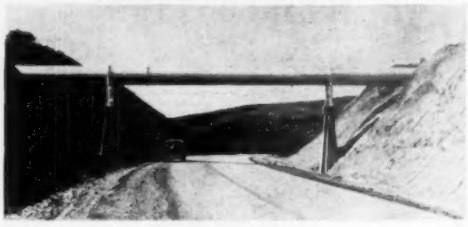


Fig. 5 Typical highway crossing long span pipe

DESIGN

It has been the practice of engineers in our company to use a maximum allowable stress in the ring girder for pipe fully loaded of 10,000 psi. and a maximum ring stress of 18,000 psi. when the pipe is half full of water

Sewage disposal long span pipe

111 in. pipe supported on concrete piers

96 in. siphon erected by ginpole

Sections of 84 in. pipe assembled and welded complete before skidding to final position

Figures 6-9

which is the period of greatest stress for lines operating under a very low head.

For the pipe shell a maximum stress of 10,000 psi. is allowed to meet the worst loading conditions.

Usually the stresses in the pipe when full and under pressure are the critical stresses to which the design stress of 10,000 psi. applies.

Higher strength materials should now make higher working stresses common practice, resulting in thinner walls and longer spans. I understand the U. S. Bureau of Reclamation at one time made a tentative design for a 300-ft. span pipe.

FIELD ERECTION

One of the chief advantages of self-supporting long-span pipe is the ease of field erection when compared with other structures.

If the pipe is supported on steel bents or concrete piers the entire span can often be assembled on the ground and placed to the permanent position after welding. Fig. 5 shows a 24 in. diameter $^1/_4$-in. wall long-span pipe shipped in two 35 ft. lengths, which was welded together on the ground and erected complete in a matter of hours.

If the weight involved is beyond the capacity of the erection equipment then each pipe section must be handled independently and some falsework is necessary until the complete span is in place. Fig. 6 shows a section of 111-in. diameter pipe being erected. This section was butted on to the end of the pipe already laid, checked for line and grade, tacked in several places and supported by a timber A frame until the pier piece was erected to complete the span.

The exact erection procedure will depend on: (*a*) the capacity of the erection equipment and (*b*) the terrain and other physical limitations. A drag line or crane is usually used for erection but occasionally the pipe must be installed on the side of a mountain or other locations where heavy hoisting equipment would be impractical and the cost of an aerial tram for such a short job prohibitive.

In such cases a gin pole or an A frame is usually used. Fig. 7 shows a 45° elbow 96 in. diameter being set into place with a gin pole. This is of course slow hazardous work and I would recommend that it be used only as a last resort.

Another example of a location unfavorable to heavy equipment is this sewage disposal line shown on Fig. 8. This pipe is 78 in. diameter two spans of 105 ft. each. Some of these sections weighed over ten tons.

The river bed was too soft for a crane so wooden mats 10 ft. square were lashed to a pair of 60-ft. gin poles to form an A frame. A winch truck on the bank completed the erection equipment.

Long-span pipe can often be assembled into position without a lot of costly falsework. Fig. 9 shows a number 84-in. pipe being tacked and welded along a bank. There was a deep gully in front of the tunnel. To erect this long span the conventional way would have required a falsework of timbers to support the pipe until it was erected and welded. Instead the pipe was tacked and welded along the bank, blocked inside with timbers to retain its cylindrical shape, then skidded into position by a winch truck, Fig. 10. Since all the erection and welding was performed at ground level much saving in time was effected.

Unequal expansion caused by the suns rays on the pipe presents a serious problem in installations. The writer has experienced a severe example of this during the erection of a 52-in. pipe in the Rocky Mountains, Fig. 11.

The temperature differential between 6:00 A.M. and 1:00 P.M. was perhaps 60°. Approximately 350 ft. of pipe was laid onto the concrete piers. The morning had been cool and cloudy. When we returned from lunch to the job site we discovered that the afternoon sun coming from behind the clouds heated one side of the pipe and caused such a bow from expansion that it actually fell off the pier.

In theory the only consideration in erecting pipe is to set it to a given line and grade. However, if the sun heats only one side of the pipe and a lateral deflection moves the pipe in a horizontal position then center lines

Fig. 10 210 ft. of 84 in. Pipe skidded into position by winch truck

Fig. 11 Jim creek siphon

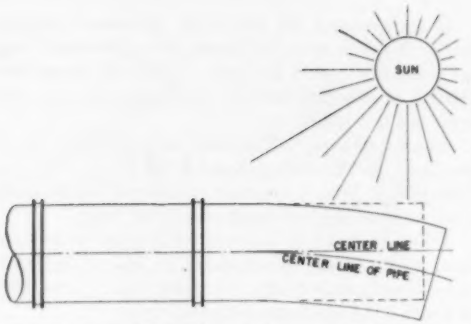


Fig. 12 Lateral deflection of pipe caused by Sun Rays

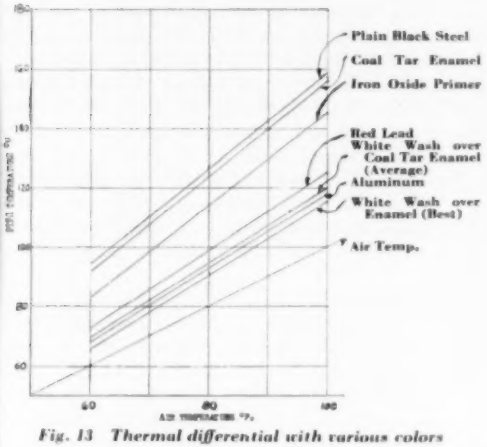


Fig. 13 Thermal differential with various colors

lose their significance. Fig. 12 shows an exaggerated drawing of this condition.

Assume that several lengths of pipe have been erected on piers and joined together. The sun is low and has heated one side of the pipe only. The next section being erected is placed to correct line and grade. The obvious result is a very poor fit-up at the girth seam. As more pipe is laid this deviation from the true center line becomes accumulative. A correction must be made eventually in order to get the pipe back to correct center line.

If the false center line is used to set the pipe then the true center line may be off several inches when the sun goes down and the pipe has an even temperature around the entire girth.

I should like to be brilliant enough to give you a formula to figure the expansion along this heated side and be able to tell you just how much the pipe will move. However, only experience and good judgement will suffice.

The erection gang does become proficient in guessing just how much movement will take place and this is taken into consideration when setting the pipe.

Color may also be used to control pipe distortion. Quite a number of years ago we discovered that whitewash sprayed on the outside of a pipe would make it a reasonably comfortable place to work inside, otherwise it may be impossible or at least a very uncomfortable place to work.

Today we use color to control the temperature of not only the inside of the pipe but to lower the temperature of pipe coatings such as plasticized coal tar enamel. Many of these long-span pipes are lined with this material.

If this enamel is allowed to reach a temperature of over 100° F. it would become so soft that the abrasion it receives from the erection crew would ruin it.

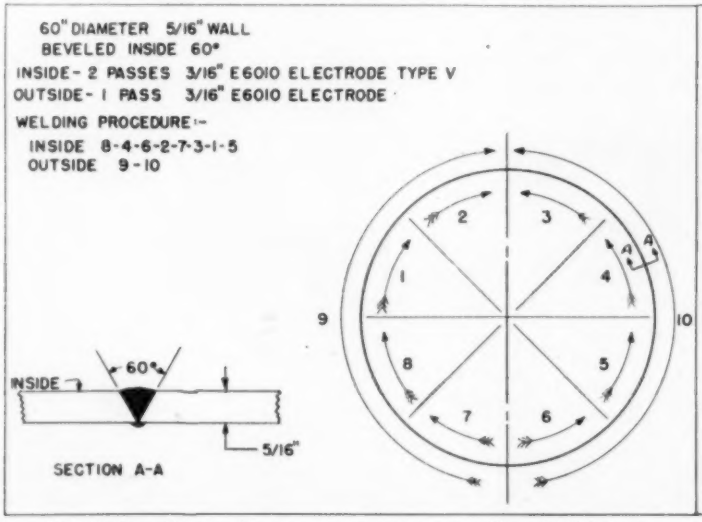


Fig. 14 Procedure used to prevent movement caused by weld shrinkage

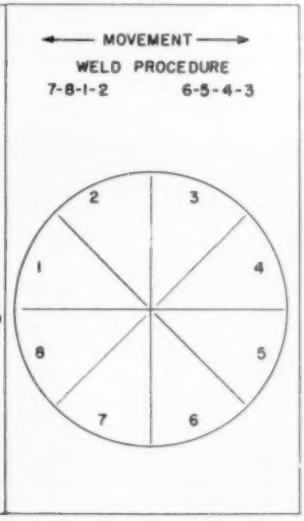


Fig. 15 Procedure used for correct alignment

Fig. 13 shows the results of a test made by the U. S. Bureau of Reclamation. Steel plate samples were placed on wooden racks after being painted with various paints and coatings. A thermocouple was attached to each sample and then to a recording thermometer. Readings of temperatures were recorded at an air temperature of 60, 80, 100° F., respectively. The "good" and "average" whitewash referred to in the second and third columns were judged by the whiteness and coverage.

It is interesting to note that contrary to popular belief the plain steel which was not nearly as black a color as the coal tar enamel registered the highest temperature.

I emphasize again that the sun can be a serious problem to the pipe erector. You simply have to learn to live with it.

WELDING PROCEDURE

Needless to say, a thoroughly competent welding operator capable of qualifying under A.W.W.A. A.W.S. and other codes must be employed if a safe and satisfactory field-welded installation is to be made.

The welding procedure to either correct alignment or to hold correct alignment can also be determined by experience. Fig 14 shows the procedure used on a 60 ft-$^{5}/_{16}$ in. wall-pipe beveled inside 60°.

This procedure was used when the pipe was set to correct line and grade. Corrective movement was not desired.

If the pipe was out of alignment and movement was needed for correction then a procedure similar to this in Fig. 15 was used.

These procedures are based on the following conditions:

a. One or more pipe has been laid to correct grade and line.

b. An adjacent pipe has been laid, tacked and found to be off the actual center line.

c. The laid pipe is blocked and restrained from movement.

It isn't often that we are privileged to witness a test of long-span pipe under conditions that are similar to full-size destructive tests. Mother Nature provided us with a test of pipe line that we fabricated and installed in the mountains near Denver.

Fig. 16 Welded steel pipe is tough

A cloudburst washed tons of rocks, trees and debris along side a 96 in. diameter $^{1}/_{4}$-in. wall line used as a siphon between two tunnels (Fig. 16).

In spite of this severe abuse careful examination revealed no mentionable damage.

CONCLUSION

The practicability and economy of long-span pipe will continue in popularity when used as a conduct over rocky ground, highways and rivers where the cost of excavating may be prohibitive or impractical.

The writer is indebted to G. E. Burnett, U. S. Bureau of Reclamation for his information regarding the temperature of colors.

References

Garrett, Garland H., "Design of Long-Span Self-Supporting Steel Pipe," *J. Am. Water Works Assoc.*, **40** (11), Nov. 1948; *Welding Handbook* 1950, Transmission Pipe Lines, pp. 1305-1372.

Spot Welder Secondary Current Measurement

A new method for measuring repeat accuracy of the secondary current in a spot welder for production work is described

by I. C. McKechnie

DURING the development of a new spot welder, the author found it desirable to measure the secondary current.

The accurate measurement of the secondary current of a spot welder is a difficult problem. The flow of current is of short duration, the magnitude high, and the magnetic field in the vicinity of the secondary loop of such intensity as to render most instrumentation inaccurate.

The *R.W.M.A. Bulletin No. 2* of May 1940 describes two methods of obtaining secondary current measurements in common use today. The standard "Set Up" condition is the substitution of 8 in. of copper bar, (6 in. on small welders) of the same cross section as the electrode holder, between the arms in place of the electrodes, points and work. Under this condition, common practice as noted in the bulletin is to measure the primary current using a current transformer and ammeter with pointer stops, then multiply by the turn ratio.

The accuracy of this method is backed up by data showing comparative results obtained with this method and by using a Cathode Ray Oscilloscope with a special current transformer placed around the electrode for pickup.

Since the author was particularly desirous of determining the repeat accuracy of the welder, especially on welds of short duration—1 to 6 cycles—neither of the above methods proved satisfactory. For time intervals this short, readings were extremely difficult to observe and results were very erratic.

Probably the most serious defect that can exist in a welder, and the one that has been given considerable attention by engineers, is repeat accuracy with a given control setting. The inability of a welder to maintain repeat accuracy results in production rejects or excessive burning in attempts by the operator to use control settings hot enough to cause even the poor welds to hold. Synchronized and phased timers and contactors have been developed to maintain repeat accuracy and to reduce transient current surges which affect short time weld repeat accuracy.

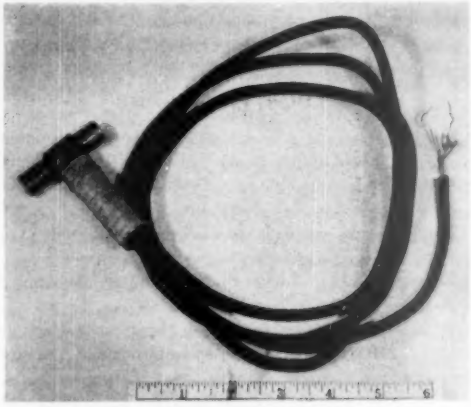


Figure 1

A more accurate method of measuring the heat—I^2R—developed on successive short time welds was essential to the proper evaluation of welder transformer and control design.

This thought resulted in the development of what appears to be a more reliable method of measuring secondary current.

A copper rod $^1/_2$ in. in diameter and long enough to have an electrical resistance equal to 8 in. of electrode holder (6 in. of small welders) is fitted with a fine wire thermocouple and handle. See Fig. 1.

This rod is then inserted between the welder electrodes which are clamped on the rod ends until the rod temperature stabilizes to the electrode temperature; then the welder is fired. Immediately upon firing, the electrodes are opened and the rod allowed to hang free in still air while the temperature rise of the rod is read on a potentiometer.

The heat generated, hence the temperature rise of the rod, is proportional to the square of the current times the duration. For easy use, the curve shown in

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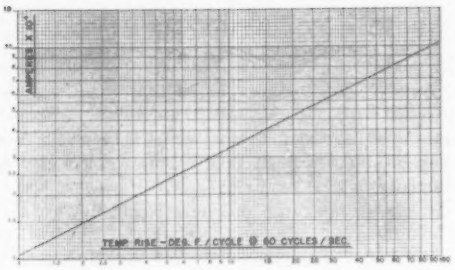

Figure 2

Fig. 2 gives amperes vs. values of rod temperature rise per cycle, in ° F., for 60-cycle power frequency.

The only precautions that appear to be necessary to obtain accurate results are: (1) Use flat electrodes larger than the rod diameter, one of them preferably of the swivel type. (2) Clean the oxide from the electrode faces and rod ends with fine crocus cloth at frequent intervals. (3) Drop the copper rod out from between the electrodes immediately after firing.

If the welder being tested is equipped with an accurate timer, the temperature rise per cycle can be calculated directly from the timer setting, otherwise it will be necessary to connect an accurate time measuring device to the transformer primary, such as a good cycle counter.

The following chart is a record of actual data taken on a welder:

Heat setting	*Cycles*	*Temperature ° F., Initial*	*after firing*	*Rise*	*Rise/cycle*	*Amp.*
4	2	61	63	2 0	1 0	10,200
4	2	61	63	2 0	1 0	10,200
4	4	62	65	3	0 75	9,000
4	4	62	65	3	0 75	9,000
4	4	61	64	3	0 75	9,000
4	8	62	69	7	0 875	9,800
4	8	62	69	7	0 875	9,800
8	2	62	67	5 0	2 5	16,200
8	2	62	67	5 0	2 5	16,200
8	4	62	74	12 0	3 0	18,000
8	4	62	77	15 0	3 75	20,000
8	4	61	75	14 0	3 5	19,300
8	8	61	89	28 0	3 5	19,300
8	8	61	91	30 0	3 75	20,000

The above welder shows remarkable repeat accuracy in the range from two to eight cycles on two different heat settings. Actual weld tests made on the same welder verified the results obtained.

Measurements made at the same time of primary current on a long time cycle indicate the following secondary current:

Heat setting	*Pri. amp.*	*Turn ratio*	*Calculated secondary, amp.*
4	205	40	8,200
8	410	40	16,400

Since the time required to obtain the above readings was in the order of 120 cycles, the resultant heating of the primary would account for the lower calculated amperage values obtained.

The author has found this method invaluable in obtaining accurate data for evaluating the performance of various welder components.

One point that should be considered, should this method of measuring current meet with general approval, is the diameter and resistance value of the copper rod to be heated. As stated previously, the author used a $^1/_2$-in. diameter rod and a length to equal the resistance of 8-in. electrode holder.

The diameter of the rod may be varied to increase or decrease the temperature rise obtained per cycle. Since too high a total temperature rise will result in excessive heat loss to the air, and too low a rise will require increased accuracy of the temperature recording equipment, the $^1/_2$-in. diameter was selected as a most likely compromise.

The length of rod may be varied to add any desired series resistance to the secondary loop independent of temperature rise. (See formula developed below.) *R.W.M.A. Bulletin No. 7* of February 1942 shows values of secondary equivalent resistance for various stock thickness. Since measurements using the Copper Rod Ammeter are made with electrodes in place, thus including electrode resistance in the secondary loop, it would seem desirable to use a length of rod to give the equivalent resistance of some average stock thickness rather than an arbitrary 8 in. of electrode holder: for instance two thicknesses of $^1/_{16}$ in. stock.

FORMULA DEVELOPMENT

The temperature rise of material due to the flow of electric current, (assuming no heat loss to surrounding media) is directly proportional to I^2R or watts, and the length of time of flow, and inversely proportioned to the specific heat, and weight of the material.

We write:

$$\text{Temp. rise} = \frac{I^2R \times \text{Time} \times \text{Constant}}{\text{Spec. heat} \times \text{weight}} \qquad (1)$$

Since the resistance of a material is directly proportional to the resistance per unit volume and the length in the direction of current flow; and inversely proportional to the area, we have

$$R = \frac{\text{Spec. res.} \times L}{A} \qquad (2)$$

And the weight of a material is a function of the weight per unit volume (Density) multiplied by the volume, so

$$\text{Weight} = \text{Density} \times L \times A \qquad (3)$$

Substituting these values in the temperature rise formula, we have

$$\text{Temp. rise} = \frac{\text{Spec. res.} \times L \times I^2 \times \text{Time} \times \text{Constant}}{A \times \text{Density} \times L \times A \times \text{Spec. heat}} \qquad (4)$$

Since L appears in both the numerator and denominator, it cancels out. In other words, the length of an electrical conductor has nothing to do with its temperature rise for a given current.

Simplifying, we have:

$$\text{Temp. rise} = \frac{\text{Spec. res. x Time x } I^2 \text{ x Constant}}{A^2 \text{ x Density x Spec. heat}} \quad (5)$$

Using the metric system of measurement:

A in cm.^{2}
Spec. resistance in ohms/cm. cube
Spec. heat in cal./gm. ° C.
Density in gm./cm.^{3}
Time in cycles at 60/sec.
Temp. in ° C.

and the conversion constant factor:

$$1 \text{ cal.} = 4.186 \text{ Watt sec.}$$

We can write:

$$\text{Temp. rise, ° C.} = \frac{\text{Spec. res. x Cycles x } I^2}{60 \text{ x Spec. heat x Density x } A^2 \text{ x } 4.186} \quad (6)$$

Now let Rc = Temperature rise degree C./cycle
Substitute:

$$Rc = \frac{\text{Spec. res.x } I^2}{\text{Spec. heat x Density x } A^2 \text{ x } 251.16} \quad (7)$$

Solving for I:

$$I = 15.84\, A \sqrt{\frac{Rc \text{ x Spec. heat x Density}}{\text{Spec. res.}}} \quad (8)$$

For a $^1/_2$-in. diameter hard-drawn copper rod:

Spec. heat = 0.09305
Spec. res. = 1.77×10^{-6}
Density = 8.89
$A = \pi 0.25^2 \times 6.4516 = 1.2661$ sq. cm.

$$\sqrt{\frac{\text{Spec. heat x Density}}{\text{Spec. res.}}} = 684 \quad (9)$$

$$I = 15.84 \times 1.266 \times 684 \sqrt{Rc} \quad (10)$$

To convert to ° F. Rise/cycle = Rf

$$I = 13700 \sqrt{\frac{Rc\ 5}{9}}$$

$$= 10200 \sqrt{Rf} \quad (11)$$

Current values for various values of Rf have been plotted on the attached curve sheet (Fig. 2).

SOME CALCULATIONS ON MATERIAL WELDABILITY

Every welder engineer knows that some materials are much harder to spot weld than others. Mild steel seems to be the easiest. Aluminum has been considered more difficult. Surface conditions of the material undoubtedly affect its weldability. However, specific heat, specific resistance and density probably are more of a factor.

Using the formula development above, it is possible to develop a material weldability constant which gives a fairly accurate measure of the relative ease with which a given material may be welded if we assume clean surface conditions: From formula 6 above:

$$\text{Temp. rise, ° C.} = \frac{\text{Spec. res. x Cycles x } I^2}{60 \text{ x Spec. heat x Density x } A^2 \text{ x } 4.186}$$

Solving for I:

$$I = 15.84A \sqrt{\frac{\text{Spec. heat x Density x Temp. rise ° C.}}{\text{Spec. res. x Cycles}}}$$

Now, if we neglect heat conductivity and change of resistance of the material being welded with temperature and current distribution and insert for—Temp. rise ° C.—the melting point of the material being welded, we can calculate the current necessary to weld any material in any given length of time.

For very short time intervals the above formula should be quite accurate. In the Table below are the values of current, Cw, required to make welds of one cycle duration for several different materials with an electrode contact diameter of one square Cm.

Cw can be used as a comparative weldability constant for the various materials.

Material	*Melt point, ° C.*	*Spec. heat*	*Density*	*Spec. res. x 10^{-6}*	*Cw x 10^3*
Mild steel	1515	0.113	7.83	15.9	146
Aluminum	658	0.22	2.7	2.8	188
Tungsten	3400	0.034	19.6	5.51	321
Lead	327	0.03	11.0	22.0	35.1
Copper-hard	1083	0.093	8.89	1.7	363

These calculations show that relative to mild steel aluminum requires 126% of the current and copper 245% of the current.

Using this same formula development, the author has attempted to calculate the actual current, time and pressure requirements to make any particular weld. To date, the theoretical values obtained agree with actual practice in stock thicknesses up to $^1/_{16}$ in. Additional work is now in progress.

Spot and Seam Welding of Aircraft Using D.-C. Current

Field performance of Tri-phase dry disc rectifier D.-C. welders in a number of high-production installations of aircraft materials

by J. H. Cooper

INTRODUCTION

THE bibliography of this paper contains a list of reference papers analyzing the need for and development of d.-c. resistance welding equipment as influenced by:

(*a*) Limited power supply situations.
(*b*) The desire for improved welding performance.

These papers cover the results of eight years of development, laboratory operation and field spot testing for production performance under a wide variety of conditions.

This paper is of the nature of a progress report on the field performance of Tri-phase dry disc rectifier d.-c. welders in a number of high-production installations where aircraft materials are welded to rigid government specifications.

Performance data are presented and discussed and a few typical brief case histories are related of applications by aircraft companies fabricating components to meet Army-Navy specifications on aluminum alloys (AN-W-30), stainless steels (AN-W-32), nickel alloys and plain carbon steels (AN-W-32).

CASE HISTORY AT CONSOLIDATED-VULTEE AIRCRAFT CO., FT. WORTH, TEX.

The world's largest bomber (at time of writing this paper) is the B-36, now being manufactured in large numbers as a propeller driven aircraft and flight tests are being made with supplementary jet engine drive. See Fig. 1 for B-36 in flight.

Many components are resistance welded on this large bomber and the Tri-phase d.-c. spot welder shown in Fig. 2 has been satisfactorily performing since its installation a year or so ago.

Prior to placing it into production, most complete qualification and certification tests to meet AN-W-30 and AN-W-32 requirements were made, involving the usual radiographic, shear strength and consistency, penetration, surface indentation and sheet separation tests, etc.

Fig. 1 Consolidated Vultee B-36 bomber; 10,000 mile nonstop range with 10,000 lb. bomb load half way; over 40,000 ft. service ceiling; 21,000 hp. from six engines; over 350 miles per hour maximum speed

Fig. 2 Size 3 d.-c. spot welder, 100 kva. Tri-phase, welding air scoop (0.064 52S aluminum) at Consolidated Vultee Aircraft Corp., Ft. Worth, Tex.

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Tests were satisfactorily passed on the following combinations:

(*a*) AN-A-13 aluminum alloy, 24S Clad, T condition, to AN-A-13, 24S Clad, T condition; fifty-one (51) combinations of thicknesses ranging to a maximum of two thicknesses of 0.125 in.

(*b*) AN-A-10 aluminum alloy 75S Clad, T condition, to AN-A-10, 75S Clad, T condition; fifty-one (51) combinations of thicknesses ranging to a maximum of two thicknesses of 0.125 in.

(*c*) QQ-A-318A aluminum alloy, 52S, O condition, to QQ-A-318A, 52S, O condition; fifty-two (52) combinations of thicknesses ranging to a maximum of two thicknesses of 0.125 in.

(*d*) AN-A-13 aluminum alloy, 24S Clad, T condition, to QQ-A-318A, 52S, O condition; ninety-four (94) combinations of thicknesses ranging to a maximum of two thicknesses of 0.125 in.

(*e*) AN-QQ-S-772 stainless steel, annealed condition, to AN-QQ-S-772, annealed condition; thirty-three (33) combinations of thicknesses ranging to a maximum of two thicknesses of 0.125 in.

(*f*) AN-QQ-S-772 stainless steel, 1/2 hard condition, to AN-QQ-S-772, 1/2 hard condition; twenty-six (26) combinations of thicknesses ranging to a maximum of two thicknesses of 0.125 in.

CASE HISTORY AT SOLAR AIRCRAFT CO., SAN DIEGO, CALIF.

The Solar Aircraft Co., with plants at San Diego, Calif., and Des Moines, Iowa, a major fabricator and supplier of stainless steel and nickel alloy aircraft components involving the use of resistance welding, has been using both d.-c. seam and d.-c. spot welding for a year or so.

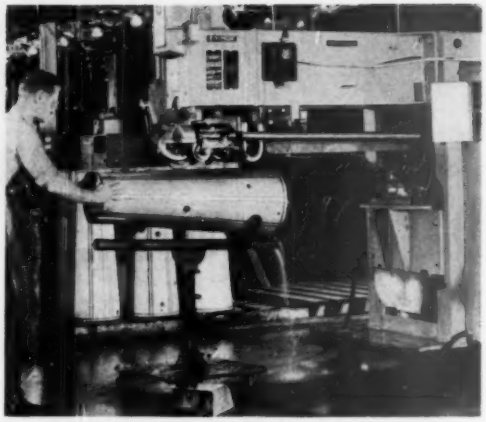

Fig. 3 Tri-phase size 2 d.-c. seam welder welding J-47 aft frame cone of jet engines at Solar Aircraft Co., San Diego plant; material is 0.050 type 347 stainless steel

A battery of four Tri-phase spot welders of the type shown in Fig. 4 have been qualified, certified and placed in production to meet the requirements of AN-W-32 involving radiographic, metallurgical, physical, etc., tests on the following materials and thicknesses which were required by Solar production:

(*a*) 18–8 Stainless steels, Types AISI 302, 304, 316, 321 and 347. Two thicknesses each of 0.010, 0.018, 0.025, 0.031, 0.043, 0.050, 0.063, 0.078, 0.093 and 0.125 in. Dissimilar thickness combinations; 0.025 to 0.078 in., 0.025 to 0.093 in., 0.050 to 0.125 in. and 0.018 to 0.031 in.

(*b*) 25–20 Stainless steel, Type 310. Two thicknesses each of 0.031, 0.050 and 0.063 in. Dissimilar metals 0.031 in. Type 347 to 0.050 in. Type 310.

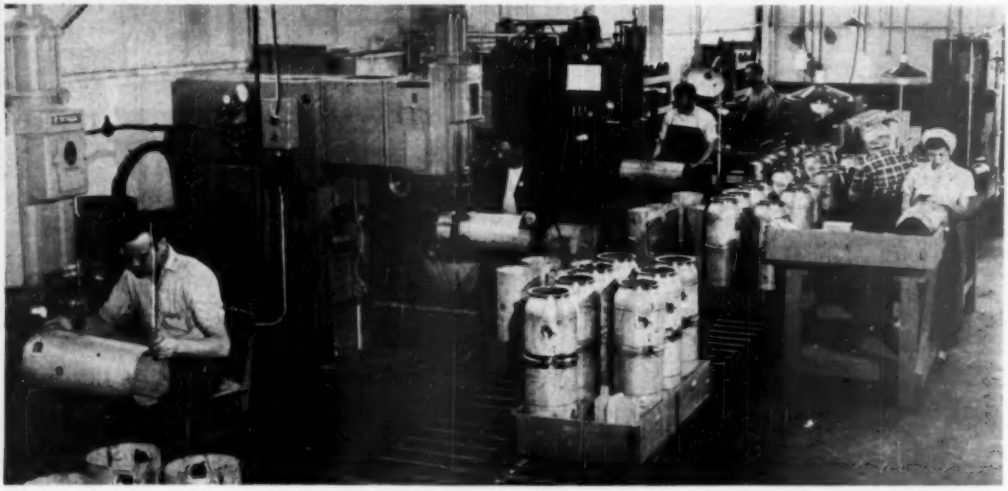

Fig. 4 Tri-phase size 2 d.-c. spot welders welding combustion chambers of jet engines at Solar Aircraft Co., San Diego, Calif.; material is 0.025 type 347 stainless steel

(*c*) Nickel alloy—Inconel. Two thicknesses each 0.031, 0.050, 0.063 and 0.078 in.

(*d*) Type N155 stainless (20% chrome, 20% nickel, 20% cobalt, balance iron). Two thicknesses each 0.020, 0.050 and 0.063 in. Dissimilar metal 0.025 in. Type N155 to 0.078 in. Type 347.

D.-C. seam welding is also being performed at Solar, see Fig. 3 showing the welding of jet engine cones, using Tri-phase equipment which has qualified for the following material and thickness combinations which were required for Solar production:

(*a*) 18–8 Stainless steels, Types AISI 302, 304, 316, 321 and 347. Two thicknesses each of 0.018 0.025, 0.037, 0.050, 0.063 and 0.078 in. Dissimilar thickness combinations; 0.018 to 0.025 in., 0.018 to 0.031 in., 0.018 to 0.037 in., 0.018 to 0.050 in., 0.018 to 0.063 in., 0.025 to 0.043 in., 0.037 to 0.050 in., 0.037 to 0.063 in., 0.037 to 0.094 in., and 0.078 to 0.094 in.

(*b*) Nickel alloy—Inconel. Two thicknesses each of 0.025 and 0.050 in. Dissimilar thickness combination, 0.025 to 0.043 in.

(*c*) Type N-155 stainless. Two thicknesses each of 0.025 and 0.050 in. Dissimilar thickness combination, 0.025 to 0.043 in.

CASE HISTORY AT DOUGLAS AIRCRAFT CO., LONG BEACH, CALIF.

This aircraft company manufactures the C-124 large cargo airplane for the Army Air Forces along with a wide variety of other military and commercial aircraft.

Figure 5 shows a d.-c. spot welder in production on an engine oil lubricating tank for the C-124, one of the many components welded on this machine in the past year or so.

Douglas has a number of these Tri-phase d.-c. welders, both press and rocker arm types. The particular Size 3 press type spot welder shown in Fig. 5 has been qualified and placed in production on a wide variety of thickness and material combinations, including a maximum of two pieces of 0.102 in. 24ST Alclad and a minimum of two pieces of 0.012 in. stainless steel.

Fig. 5 Douglas Aircraft Co., Long Beach, Calif., using a Tri-phase size 3 d.-c. spot welder to weld lubricating oil tank for C-124 large cargo plane. Material is 0.064 61ST Aluminum to 0.072 52SO aluminum

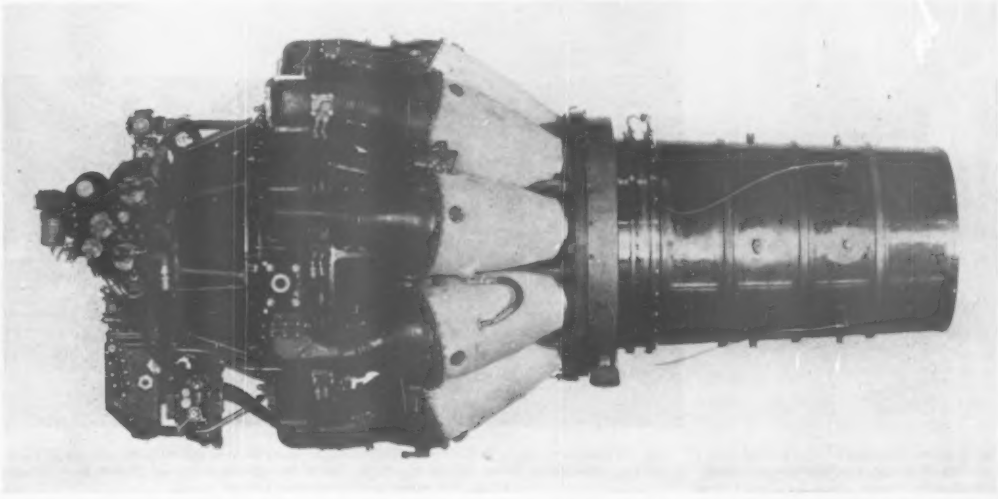

Fig. 6 Pratt and Whitney Aircraft type J-42 Turbo-Wasp jet engine containing many resistance spot and seam welds

CASE HISTORY AT PRATT & WHITNEY AIRCRAFT, EAST HARTFORD, CONN.

This company manufactures aircraft engines of both the radial cylinder type and the jet engine type. It has manufactured and has still flying the largest total of aircraft engines by any manufacturer, both in terms of numbers and horsepower.

Figure 6 shows a late design of jet engine, the J-42 Turbo-Wasp.

These engines contain resistance spot and seam welds in large numbers. Figure 7 shows one of a battery of d.-c. spot welders equipped with special lower horns for maximum work clearance. These welders also have upper and lower water jets for flood cooling of the welds inasmuch as edge-distance is often so small that welding takes place virtually at the edges of the sheets.

These d.-c. welders have been qualified and in production under the cognizance of the Bureau of Aeronautics of the Navy Department for several years on the following material and thickness combinations, as required by Pratt & Whitney production:

(*a*) AMS No. 5510 stainless steel. Minimum of 0.018 in. to maximum of 0.125 in.

(*b*) Nimonic stainless 80/20. Minimum of 0.031 in. to maximum of 0.064 in.

(*c*) Plain carbon steel. Minimum of 0.018 in. to maximum of 0.125 in.

CASE HISTORY AT GOODYEAR AIRCRAFT CORP., AKRON, OHIO

The heavy duty deep throat d.-c. seam welder shown in Fig. 10 was built especially for Goodyear Aircraft with an unusually high frame to provide a large dimension between weld line and floor level. This permits placing large diameter sections of external fuel tanks over the lower arms.

This welder will weld pressure-tight joints in 0.125 to 0.125 in. 52S$^{1}/_{2}$ aluminum or 0.091 to 0.091-in. 61ST aluminum.

Figures 8 and 9 show typical external fuel tanks, 700-gal. capacity in this case, welded on this d.-c. welder by Goodyear for the Boeing B-50D Superfortress.

This welder has been qualified, certified and in production under Bureau of Aeronautics, Navy Department, cognizance since 1948 with the majority of production being:

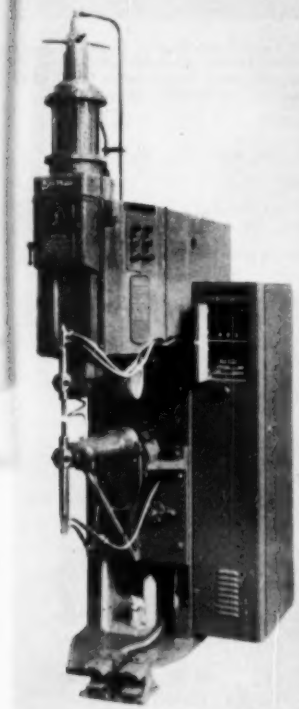

Fig. 7 One of several Tri-phase size 2 d.-c. spot welders with special water jets at electrodes used by Pratt and Whitney for welding Turbo-Wasp engines

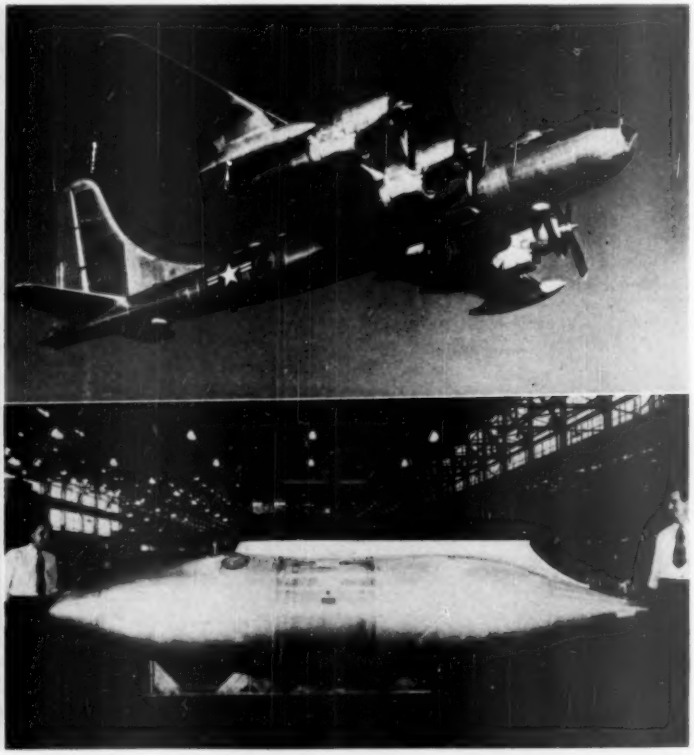

Fig. 8 Boeing Aircraft Co. type B-50D superfortress equipped with external fuel tanks; over 6000 miles normal range; total bomb capacity of 28,000 lb.; more than 400 miles per hour maximum speed

Fig. 9 700 gal. external fuel tank manufactured by Goodyear Aircraft for Boeing B-50D Superfortress, and using d.-c. resistance seam welding

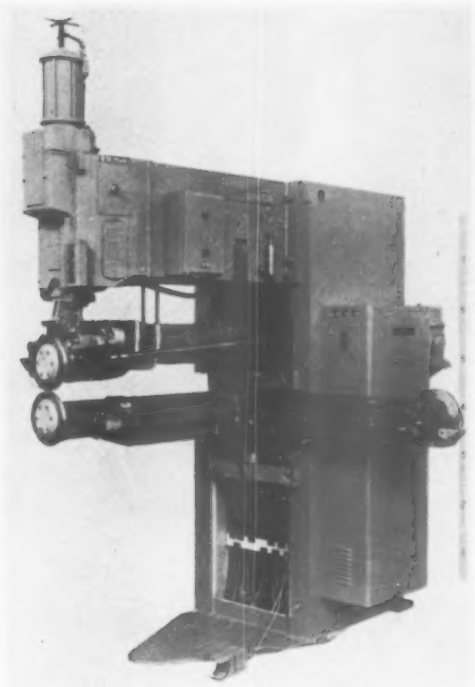

Fig. 10 Heavy duty, size 3, d.-c. Tri-phase seam welder; 54 in. throat; universal head and lower arms for longitudinal and girth seams in Goodyear Aircraft 700 gal. external fuel tanks

(*a*) Three thicknesses 0.064-in. 61ST-4 aluminum alloy.

(*b*) Two thicknesses 0.064-in. 61ST-4 aluminum alloy.

(*c*) One thickness 0.064-in. 61ST-4 aluminum alloy to one thickness 0.051-in. 61ST-4 aluminum alloy.

Performance has been outstanding in regard to weld quality and the unusually small amount of down time due to cleaning of aluminum pickup from the electrodes.

CASE HISTORY AT A. V. ROE (CANADA) LTD., MALTON, ONTARIO, CANADA

AVRO manufacture the Type C-102 Jetliner transport as well as their C-100 long range fighter and other aircraft.

Figure 11 shows the Jetliner using four Turbo-jet engines.

Figure 12 shows the Orenda jet engine manufactured by AVRO.

Miscellaneous items including flaps, skin to doors, intra-doors, radio compartments, etc. are of 24ST aluminum, welded on d.-c. spot and seam welders.

Bulkheads, fire walls, engine jet pipes and many other stainless steel and nickel alloy parts are also d.-c. welded.

Fig. 11 AVRO, Canada, Jetliner, type C-102, cruising speed 430 miles per hour at 30,000 ft.; 13,000 lb. payload; 40 to 60 passengers; operation range to 1200 miles

Qualified (AN-W-30 and AN-W-32 specifications) welding ranges for the d.-c. welders are from 0.020 to 0.081 in. 24ST Alclad aluminum and from 0.015 to 0.062-in. stainless steel to match AVRO's particular production requirements.

CASE HISTORY AT CANADAIR LTD., MONTREAL, QUEBEC, CANADA

Canadair are presently manufacturing a number of aircraft, including the North American Aviation design of F-86 Sabre jet fighters for the Royal Canadian Air Force.

Several sizes (one of which is shown by Fig. 13) of d.-c. spot and seam welders cover the range of their production requirements in aluminum ranging from 0.020 in. minimum to 0.102 in. maximum and in stainless steel from 0.020 in. minimum to 0.125 in. maximum to meet AN-W-30 and AN-W-32 specifications.

Typical examples are cable control shrouds and exhaust and tail pipes, etc., in AN-S-757 and AN-QQ-S-772 stainless steels; air-brake doors of AN-A-10 (75ST) aluminum alloy, as well as a wide variety of parts made of AN-A-13 (24ST Alclad) aluminum alloy.

CASE HISTORY AT CALIFORNIA INSTITUTE OF TECHNOLOGY, PASADENA, CALIF.

CALTECH has a division which develops and makes proto-types of new designs of aircraft components and other items on the restricted list.

To obtain an extremely wide range of weldability on all weldable sheet metals, a d.-c. welder was installed with changeable accessories and controls to permit either spot or seam welding.

Figure 14 shows this machine equipped for spot welding.

This d.-c. welder makes qualified welds to meet AN-W-30 and AN-W-32 specifications on many types of products with a seam welding range on aluminum 0.020 to 0.064 in. and stainless steel 0.020 to 0.125 in.

Fig. 12 AVRO, Canada, jet engine, Orenda type, containing many resistance welds

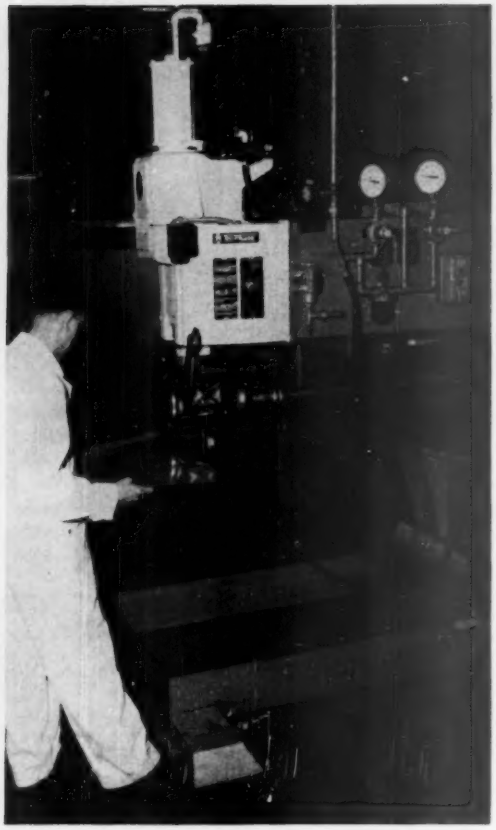

Fig. 13 One of several Tri-phase, d.-c. welders used by Canadair for welding aluminum and stainless steel components in the manufacture of F-86 Sabre jet fighters for the R.C.A.F.

CASE HISTORY AT CLIFFORD MFG. CO., WALTHAM, MASS.

Clifford manufactures a line of precision-made components, many of which are for aircraft. Such items are expansion bellows, diaphragms, oil coolers, etc., of aluminum, stainless steels and nickel alloys.

Figure 15 shows a d.-c. seam welder with very versatile type of tooling to weld cylinders from 1 in. diameter minimum to 40 in. diameter maximum.

This machine has a qualifying range to meet AN-W-30 and AN-W-32 requirements on 6180 aluminum from 0.015 to 0.125 in. and on stainless steel from 0.006 to 0.081 in.

It is significant of the flexibility of a d.-c. welder that the adjustment of welding current to weld a range from 0.006-in. stainless steel to 0.125-in. aluminum (9 to 1 current range) is obtainable by a change of only a few tap switch settings.

GENERAL COMMENTS

The limited space of this article does not permit further development of these case histories or the inclusion of information concerning a number of other applications, such as, the General Electric Co. purchasing a d.-c. welder for developmental work on aircraft superchargers, jet engines, etc.; Aircraft Radio Co. for aircraft radio components; Twin Coach, Aircraft Division, for aircraft components; Edo Corp. for Navy items; Mac-Donald Brothers Aircraft for aircraft work; Eugene's Engineering for aircraft components; Beech Aircraft purchasing a battery of four d.-c. welders to cover welding aircraft aluminum from a minumum of 0.016 in. to a maximum of 0.125 in.; as well as many installations where high quality is a necessity but the products are not for aircraft use and, therefore, not within the scope of this article.

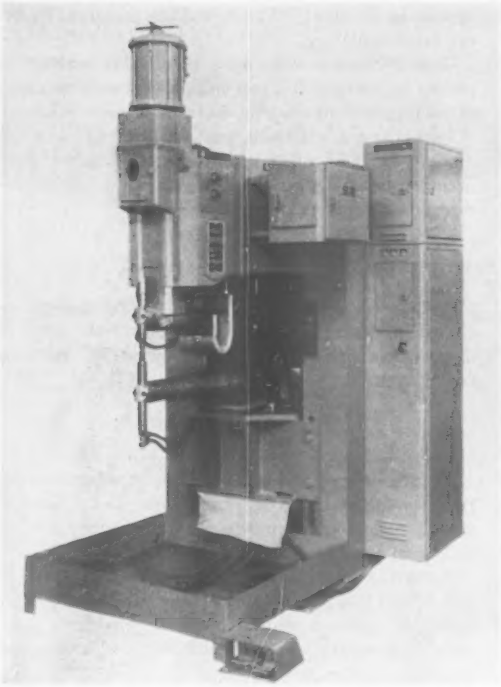

Fig. 14 Heavy duty size 3 Tri-phase combination d.-c. spot and seam welder used at California Institute of Technology. View shows machine arranged for spot welding

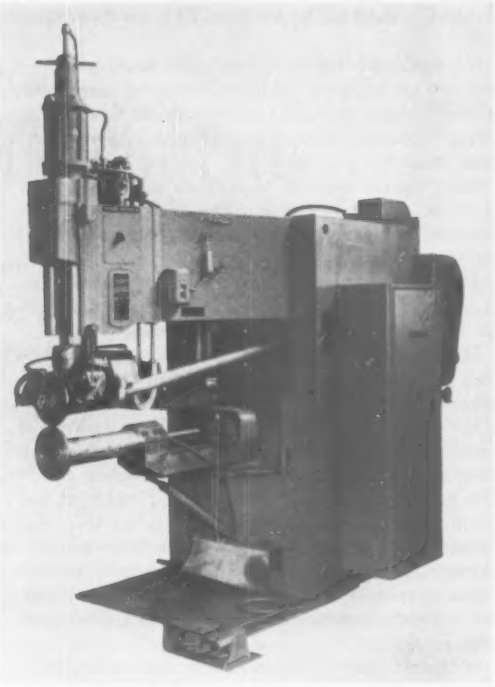

Fig. 15 Clifford Mfg. Co. uses d.-c. seam welder with changeable lower arms to weld from one to forty-in. diameter cylinders of aluminum, stainless and nickel alloys

PERFORMANCE DATA

(a) Radiographic Inspection

The qualification of d.-c. welders to meet radiographic inspection requirements of Army-Navy specifications has the foundation of generally obtaining essentially crack-free radiographs rather than take advantage of the specification tolerances on internal cracks. This policy is a conservative one so that a greater amount of leeway is given the fabricator for the variables always present in production welding, which often cause some cracks.

(b) Tension-Shear Strength of Spot Weld Shear Specimens

The qualification of d.-c. welders to meet shear strength requirements and strength consistency requirements is based on the policy of maintaining a reserve over the values indicated in the Army-Navy specifications.

Figure 16 gives actual strength values selected when qualifying on two equal thicknesses of 24ST Alclad aluminum alloy shown in comparison with the requirements of specification AN-W-30.

Consistency of qualification welds made with d.-c. welders on 24ST Alclad aluminum is such that the percentage of spots within plus and minus $12\frac{1}{2}\%$ of the average tension-shear value usually runs 95% (AN-W-30 specifies 90%) and sometimes is 100%.

Penetration of the fused zone into the two outer sheets of equal thickness runs within the limits of 40 to 75% of the original sheet thickness as checked by many sets of qualification runs with d.-c. welders. This percentage adequately meets the requirements of AN-W-30 that

MATERIAL THICKNESS	AN-W-30 AVERAGE STRENGTH	D.C. WELDER AVERAGE STRENGTH	AN-W-30 MINIMUM STRENGTH	D.C. WELDER MINIMUM STRENGTH
.016 TO .016	145 LBS.	160 LBS.	108 LBS.	145 LBS.
.020 TO .020	187	230	140	190
.030 TO .030	315	370	235	320
.040 TO .040	460	550	345	480
.050 TO .050	620	750	465	660
.064 TO .064	920	1100	690	960
.072 TO .072	1127	1320	845	1160
.081 TO .081	1400	1580	1050	1380
.091 TO .091	1700	1900	1275	1600
.102 TO .102	2048	2260	1535	1880
.125 TO .125	2830	3000	2120	2500

AVERAGE STRENGTH VALUES OF D.C. WELDER BASED ON 100 SPOT TEST WHILE AN-W-30 VALUES BASED ON ONLY 20 SPOT TEST.

Fig. 16 Tension-shear values—spot welds 24ST Alclad

penetration shall not be less than 20% nor more than 80%.

It is significant that checks made over many qualification runs involving the welding of two equal thicknesses of 24ST Alclad aluminum alloy show no detrimental effects of polarity on penetration despite opinions sometimes heard to the contrary.

Other requirements of Army-Navy specifications as to surface appearance and indentation, sheet separation and sectioning for microscopic examination are easily met.

The subject of aluminum pickup on electrodes is still as vague and controversial for d.-c. welders as it always has been for stored-energy or a.-c. welders.

Despite advertising claims often heard to the contrary, variables of the welding process such as quality of cleaning of the aluminum, uniformity and thickness of the aluminum cladding, electrode material, adequate cooling of electrodes, rigidity of welder tooling against electrode skidding on the work, proper welding schedules, etc., overshadow the question as to whether the welding current is nonpulsating unipolarity d. c. obtainable from a Tri-phase welder, single or multiple impulses of unipolarity or alternating polarity obtainable from stored energy or frequency converter welders or straight 60-cycle alternating current, with or without slope control.

With adequate technique and process control over all the variables involved in spot welding aluminum, pickup on electrodes does not constitute a hardship.

The writer is aware of one test run made with adequate process control where a d.-c. welder was welding two thicknesses of 0.064-in. 24ST Alclad aluminum to meet AN-W-30 specifications with ample reserve.

The aluminum and its cleaning were satisfactory, electrode water temperature was approximately 75° F., good tooling design was used, etc.

Aluminum pickup was considered unsatisfactory as soon as the first black spot appeared on the welded sheet as the result of etching with Keller's etch to identify break-through of the Alclad coating or copper deposit on the sheet before it could be perceived by the eye prior to etching.

Over 1000 welds were made before this evidence of pickup appeared and it can be seen that such quantity of welding without cleaning electrodes is quite practical.

In this test it was immaterial as to the effect on the number of welds which could be made before pickup occurred as to whether the d.-c. polarity remained unidirectional or reversed with each spot.

ACKNOWLEDGMENTS

Acknowledgment for the information and data included in this article is hereby given to the users of d.-c. welders with sincere appreciation for their generous cooperation.

SUMMARY

Resistance spot and seam welding of aircraft materials using three-phase dry disc rectifier d.-c. welders to meet the rigid requirements of Army-Navy specifications is an established production tested process.

Numerous installations by aircraft companies in U.S.A. and Canada, welding a wide variety of aircraft materials under a wide variety of conditions have clearly demonstrated the suitability, economy and flexibility of d.-c. welders for such applications. The inherent simplicity of the welder and electronic controls has given a high degree of continuous production and reduced maintenance cost.

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(Continued on page 1000)

Reclamation of Diesel Locomotive Parts

Preventive maintenance is an important factor in the reclamation of diesel locomotive parts. Special organizational setup and equipment are needed for maximum efficiency

by La Motte Grover and R. L. Rex

INTRODUCTION

DURING the last two years, since a paper on "Diesel Locomotive Maintenance Welding"[1] was presented by one of the authors of this paper, the use of Diesel motive power by American railroads has continued to increase at a rapid pace. Accordingly, Diesel maintenance operations have assumed even greater importance. Arc welding, gas welding and other oxyacetylene processes are playing an ever increasing rôle in these operations, as the railroads are continually striving to reduce their costs. Further experience and closer familiarity with these problems has led to more reclamation of parts and less replacements.

Most of the large users of Diesel motive power have large major Diesel maintenance shops, either in operation now or in the process of being constructed and equipped, to centralize their major Diesel maintenance operations to a large extent. However, running repairs are in general less centralized than for steam locomotives. Preventative maintenance continues to receive increasing emphasis. Some of the arc-welding and oxyacetylene process applications that were more or less in the experimental stage two years ago, have been refined or developed further for greater reliability and efficiency, and now they have become quite well standardized. Other new applications have been added, some of them being still under field trials.

There is an increased trend toward modifying the ordinary type of organization for railroad mechanical departments, to include a centralized special Diesel locomotive reclamation department under the supervision of a Diesel reclamation foreman, with carefully picked and specially trained personnel and with special equipment, including initial and final testing equipment; also with facilities for packaging for storage and facilities for shipment for reuse. Railroads that have adopted such an organization for Diesel locomotive reclamation work have found that it has greatly increased their efficiency.

RECLAIMING ALUMINUM PISTONS

One of the best examples of continued development and refinement is in the reclaiming of aluminum pistons (Figs. 1 to 4). The earlier practices of using oxyacetylene welding and conventional arc welding with aluminum stick electrodes have been replaced largely by inert-gas-shielded arc welding to save time and cost, and to provide higher quality weld metal than that deposited with aluminum stick electrodes. The tungsten-electrode inert-gas-shielded process, with the filler metal fed separately into the arc Figs. 2 and 3, has come into general use where the volume of alumi-

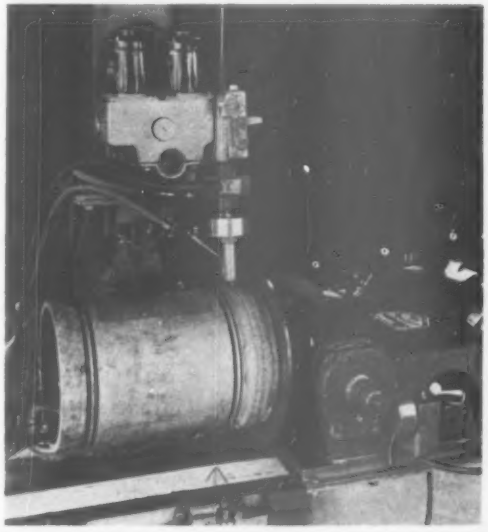

Fig. 1 Building up the worn ring-groove area of an aluminum piston by the automatic inert-gas-shielded metal-arc welding process employing a continuously fed filler-wire electrode

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[1] Rex, R. L., "Diesel Locomotive Maintenance Welding," THE WELDING JOURNAL, **27** (12), 1034–1042 (1948).

num pistons to be reclaimed is not large enough to warrant the cost of the somewhat more elaborate equipment required for the newer inert-gas-shielded metal-arc welding process employing a continuously fed filler-wire electrode Fig. 1. However, the operating costs are considerably lower for the latter.

The most commonly occurring defects to be repaired are cracks or heat checks in the middle of the head of the piston (and around lugs, if the piston is of the type with lugs), for which manual welding is used; also worn ring grooves, for which the automatic (Fig. 1) or semiautomatic processes are more efficient, provided the number of pistons to be reclaimed warrants the cost of automatic equipment.

Whether or not a damaged piston warrants reclamation depends upon a number of factors; the extent of the surface involved, the character of the damage and whether its location is such that it can be repaired by continuous welding while the piston is being revolved on turning rolls or by some other device. If the piston is badly scored it is difficult to prepare, and the welding usually must be done largely with a manual holder while the piston is stationary rather than revolving. Damaged surface areas near mid-height require intermittent manual operation because the surface is interrupted by the wrist-pin bore.

On the other hand, even when the main compression seal-ring grooves near the top of the piston are worn quite badly, resulting in slap and blow-by or loss of compression, it is economical to repair such damage. Also a limited amount of localized cracking or spalling, and often a moderate amount of scoring can be repaired to good advantage by welding. Experience in any shop will indicate how badly a piston may be damaged and still be worth while reclaiming.

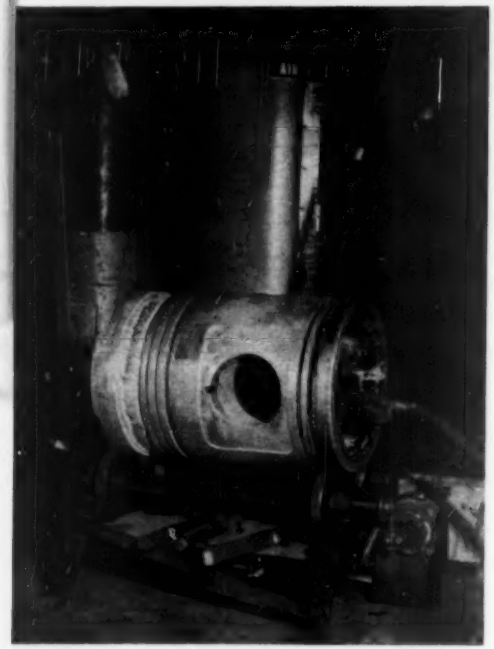

Fig. 2 Aluminum piston on positioning rolls where ring-groove area is being built up by the manual tungsten-arc process of inert-gas-shielded welding

Insulated cover, shown in Fig. 3 has been removed to show details of setup

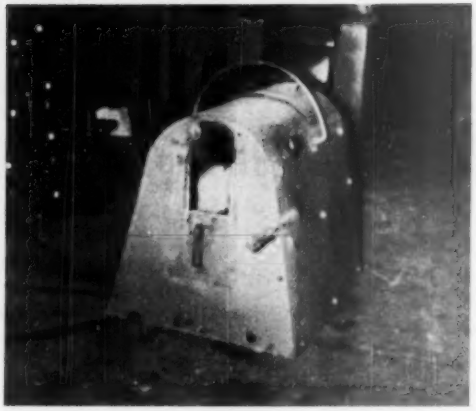

Fig. 3 Insulated cover placed over aluminum piston during welding of ring-groove areas by tungsten-arc process

Note opening in end of cover for insertion of oxyacetylene heating torch

Fig. 4 Aluminum pistons after reclamation by inert-gas-shielded arc welding and finish machining have been completed

Both of the inert-gas-shielded welding processes that have been mentioned are available in either the manual or automatic type. Sometimes the manual gun of the filler-wire-electrode type (which is semiautomatic) is clamped with a nozzle in a vertical position over a revolving piston to build up worn ring grooves.

The application of one or the other of these inert-gas-shielded welding processes for reclaiming the large one-piece types of aluminum pistons has now become quite wide-spread. Although some experimental work has been done on a smaller type of piston with a shrunk-on sleeve that carries the upper ring-grooves, the reclamation of this type has not been developed to the stage of practicality, except to replace the ring carrier with a new one.

Cost figures from one source indicate that when all the ring grooves require rebuilding, for a one-piece aluminum piston of the type with lugs on the head, and

when the machining to prepare it for welding is done as shown in Fig. 5, the total cost of reclamation, including preparatory machining, welding, finish machining, incidental operations and overhead, is less than 20% of the cost of a new piston (less than 40% of the previous reclamation cost). For the larger more costly type with dished head and no lugs, the total reclamation cost is little more than 15% of the cost of a new piston. Very frequently only one or two ring-grooves at the top need rebuilding, and the time and cost are considerably less. The time required for welding one of these pistons varies from 30 to 75 minutes, depending upon the extent of the wear or damage.

Some Diesel manufacturers have proposed the use of replacement rings that are oversize in width a sufficient amount to permit the machining of worn ring grooves, rather than repairing the piston by welding and then machining it to fit standard-width rings. However, since this practice requires the stocking of two sizes of rings, it may cause confusion, and experience indicates that railroads, in general, prefer to reclaim the pistons and to stock only standard-width rings.

To facilitate continuous operation in building up worn ring-grooves, the piston can be mounted on a turning-roll type of positioner with knurled rollers, driven by a small motor such as those that are used for driving small oxyacetylene cutting machines, equipped with a foot-switch control that will also reverse the direction of rotation.

Alternatively the piston may be mounted on a lathe-type fixture which causes it to revolve, with both ends of the piston supported; and in the case of automatic welding, the progress of the electrode holder is governed by the travel-carriage mechanism of the lathe, as it travels along the length of the ring-groove area.

The procedures that have been used for the inert-gas-shielded process with filler-wire electrode to weld aluminum pistons are given in Tables 1 and 2, when preparatory machining is done as shown in Fig. 5.

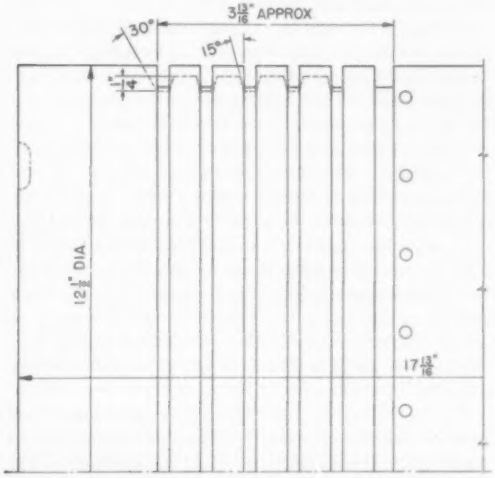

Fig. 5 Diagram showing extent of machining of worn ring-grooves of aluminum piston, 12 1/2 in. diameter by 17 13/16 in., in preparation for reclamation by inert-gas-shielded welding

Table 1—Procedure for Welding Ring-Grooves with Automatic Aircomatic Head

Preheat	300 to 350° F.
Welding current	330 to 375 amp., d. c. (long arc)
Filler metal wire	1/8 in. diameter, 43S aluminum
Shielding gas	Helium
Revolving speed of piston	1 1/2 to 3 rpm.
Number of layers deposited	Six (three in the machined grooves and three across the full width of the ring-groove area being repaired)

Remarks: No auxiliary cooling nor heating used during welding. Temperature of piston at finish of welding is between 600 and 700° F. After welding, piston is allowed to cool slowly in a preheated furnace or steam-heated cabinet.

Table 2—Procedure for Welding Ring-Grooves with Aircomatic Manual Gun Mounted on a Fixture

Preheat	300 to 350° F.
Welding current	300 to 330 amp., d. c.
Filler metal wire	3/32 in. diameter, 43S aluminum
Shielding gas	Helium
Revolving speed of piston	1 1/2 rpm.

Remarks: Same as for Table 1. The time required for welding a piston with the manual gun is substantially greater than that required with the automatic head.

Note: Although the procedures described in Tables 1 and 2 are producing thoroughly satisfactory weld deposits, modifications are being investigated which promise to effect even greater savings in time and cost of these operations.

It is sometimes convenient to use the same manual gun that is employed for welding cracks in piston heads to supplement fully automatic equipment, when the volume of reclamation work occasionally runs more than can be handled expeditiously with one automatic head. When the gun is manually guided, as in the welding of cracks in piston heads, a lower welding current is used, about 260 amp.

The welding is started at either end of the ring groove area that is to be built up, and it progresses toward the opposite end as the piston revolves. At the end of depositing each layer, the welding tip or head is raised a moment and the new layer is started, progressing in the opposite direction, and so on until the welding of the area is completed.

For the Tungsten-electrode process, the water-cooled manual holder with water-cooled tip is used, held by the operator rather than being mounted on a fixture, and the filler metal is fed into the arc by hand, rather than employing a filler-wire feeder. When the volume of work is sufficient to justify the extra cost of providing fully automatic equipment, the use of the metal-arc process with filler-wire electrode is preferable because of its lower operating costs for this kind of an application.

When the tungsten-electrode process is used, the rate of heat input is much less, and therefore the piston is enclosed in an insulated housing (Fig. 3), (which was removed when the photograph of Fig. 2 was taken, in order to show the details better). Also an oxyacetylene torch is mounted at the skirt-end of the piston and is kept playing on the inside of the skirt as the piston

revolves, to supplement the heat of the arc welding on the ring-groove areas, and to keep the heat distributed uniformly.

The procedure used for the Tungsten-electrode process in this application is given in Table 3.

Table 3—Procedure for Welding Ring-Grooves by the Tungsten-Electrode Inert-Gas-Shielded Process

Preheat	400° F.
Welding current	375 to 425 amp. (balanced a. c.)
Filler-metal rod	3/16-in. diameter (5% drawn silicon aluminum)
Electrode	3/16-in. tungsten
Shielding gas	Argon
Revolving speed of piston	As required for manual feeding of filler rod
Number of layers deposited	3 to fill machined grooves and 3 layers over entire width of ring-groove area being repaired.

Remarks: Water-cooled holder with water-cooled nozzle. Piston heated during welding to keep heat uniform, but temperature of piston kept under 500° F. After welding, piston is allowed to cool slowly in a preheated furnace or steam-heated cabinet.

As a typical example, one shop has reported that it requires about 2 1/2 hr. per piston for reclamation by the tungsten-arc process, when only the top ring-groove must be rebuilt and some eight thermal cracks repaired in the head of the piston; and 5 to 6 hr. when the entire ring-groove area is rebuilt.

Regardless of what process is used, the piston is soaked first in a carbon solvent for cleaning, and all cracks are carefully veed out down to sound metal.

Experience has shown that when proper procedures are used, pistons reclaimed by any of the inert-gas-shielded arc processes will stand up in service at least as well as new pistons.

CAST-IRON CYLINDER HEADS

Cracking in cast-iron cylinder heads is still an important problem, despite some improvements that have been made in the design and proportions of such heads (Fig. 6). These cracks usually occur from one valve seat across to another or to the fuel injection opening,

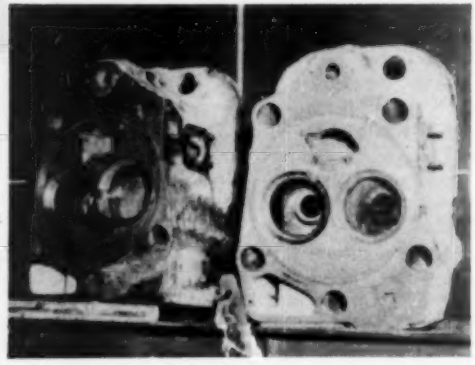

Fig. 6 Cast-iron cylinder heads with cracks veed out, preparatory for welding

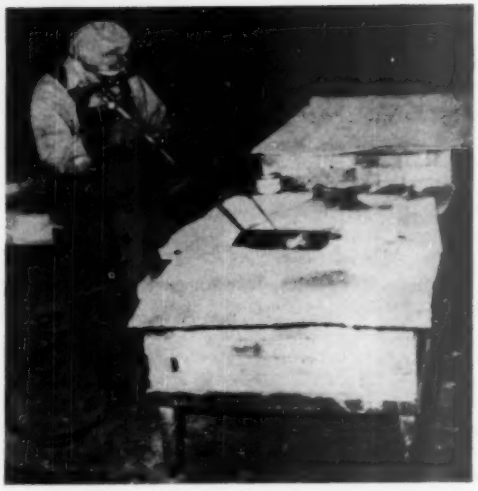

Fig. 7 Welding a cast-iron cylinder head in an insulated furnace which maintains the 1400° F. preheat temperature

or in the turbulence chamber, or in the inlet and exhaust valve chambers and sometimes at guide-bolt holes.

Although a number of processes and procedures have been tried out by various railroads for reclaiming such cylinder heads, experience indicates that oxyacetylene welding with a molybdenum cast-iron rod and suitable flux (Fig. 7), is in general the most satisfactory process, by far, largely because of its versatility. Some cracks are inaccessible for welding by any other process, and when sand pockets or other rather deep-seated defects are encountered in the castings, the oxyacetylene process is the only one that affords an opportunity for the kind of manipulation of the rod and torch that is necessary for working out such defects.

Satisfactory results have been obtained by the tungsten-electrode inert-gas-shielded arc-welding process (using argon gas and either balanced a. c. current or d. c. straight polarity) for building up worn valve seats and for repairing cracks that are accessible, when no sand pockets or other deep-seated defects are encountered in the castings. However, one cannot foresee the encountering of such hidden defects. Also, it has been found that occasionally a crack that can be reached only with the oxyacetylene welding, is not detected until the heat of welding starts to open it up. Further, when the electrode holder must be inserted in an opening such as an exhaust valve chamber, to reach a crack or defect, the proximity of the surrounding highly preheated base metal will likely result in the holder being damaged by the heat.

The cracks may be veed out by grinding or machining prior to welding, or it may be found more expedient to wash them out with the torch while the welding is being done. Machined carbon plugs with land-shoulders are inserted in all valve openings and in the fuel injection opening, to dam off the deposited metal and to pro-

vide for sufficient build up of sound metal at the edges of such openings.

With either of these processes the cylinder is preheated to about 1400° F. and welded in an asbestos lined box or insulated furnace (Fig. 7), the preheating temperature being maintained during welding. The heads are then allowed to cool slowly over a period of at least 48 to 72 hours. Some shops use a longer cooling period. The gas-welded heads are sometimes left to cool in the box or furnace where they are welded, after flake asbestos has been packed around them, and the box or furnace covered. The heads that are welded by the tungsten-electrode method are reheated and then cooled slowly in the furnace or insulated box.

Although metal-arc welding with stick electrodes has been tried for reclaiming these heads, there appears to be no record of experience that would justify a departure from the long-established requirement for preheating and annealing, as outlined above, when welded cast-iron parts are to be subjected to such severe conditions and changes in temperature as those for a Diesel head.

After cooling, the heads are machined on a radial drill press or vertical boring mill. Some types of heads require that the entire face be built up by welding to provide for subsequent machining because the general design is such that no appreciable departure from original dimensions can be tolerated.

The reclamation cost of such heads has been reported as varying from 10 to 60% of the replacement cost, depending upon the type of head and the extent of the damage. Long service records have now demonstrated the success of this operation.

Various railroads have encountered no difficulty in setting up and carrying out these cylinder head reclamation operations in a successful manner, but it cannot be stressed too much that a shop should not attempt these operations without going into the matter right. Suitable and adequate equipment must be provided; correct procedures must be established and adhered to rigidly, and competent and specially trained operators must be developed; because there are some unusual techniques and manipulation that are needed at times to assure a dense, nonporous, machinable deposit, and to hold the warping of the cylinder head face to a minimum. In training operators for this work, it is well to start them out on scrap heads that are too badly damaged for reclamation.

CAST-IRON CYLINDER LINERS

When cast-iron liners of Diesel cylinders become pitted on the water side of the liner, they are reclaimed by metal-arc welding, using an extruded electrode with a commercially pure nickel core wire. The welding is often done with little or no preheat, using a skip welding technique to avoid local overheating and to keep the heat balanced and distributed so as to minimize distortion.

The pitted areas are first cleaned out thoroughly to bright metal. This can be done most easily with a rotary file.

When the procedure and technique are controlled carefully, the out-of-round distortion after welding can be held to 0.001 in. or less, which is comparable to the tolerance for a new liner. With proper care to avoid excessive welding, no subsequent grinding is necessary.

One railroad has reported the complete cost of this operation as little more than one-tenth of the cost of a new liner.

ROLLER-BEARING JOURNAL BOXES AND OTHER BEARING SURFACES

Two important reclamation operations are now carried out quite widely on roller-bearing journal box assemblies, by means of arc welding: building up wheel thrust end bearings, and applying new manganese steel or high carbon steel wear-resistant liners on the boxes or on the pedestal jaws of the trucks.

The process of rebuilding thrust bearings for Diesel roller-bearing journal boxes with a lead-bronze wearing face has been in use now for some three years with universally satisfactory results when the proper procedure is used. This process has been used successfully for a much longer period of time for driving box laterals of steam locomotives.

The first procedure developed for these Diesel thrust pads was patterned after the common practice used for driving box laterals. It involved the depositing of two or three $^1/_8$-in. layers of lead bronze on the worn face of the existing lead-bronze pad, using 200 to 300° F. preheat and a $^5/_{16}$-in. lead-bronze self-fluxing bare electrode with about 225 amp., d. c. reversed polarity welding current.

The present trend in practice is to remove the old cast lead-bronze entirely, by the carbon-arc method, down to the cast steel, for the original reclamation, and to build up by arc welding with a phosphor-bronze electrode to within $^3/_8$-in. of the final standard surface contour, prior to depositing the facing of lead-bronze. This procedure facilitates control of porosity. A certain amount of porosity occurs invariably in depositing a lead bronze by welding, but experience has indicated no adverse effect of the moderate amount that occurs when proper procedures are used.

Subsequent reclamations, after the original reclamation, can usually be made by depositing one or two layers of lead bronze directly upon the worn face, following the original practice, at a cost of about 35% of the cost of a new bearing.

Various other types of bronzes have been proposed and tried out for reclaiming these thrust bearings, but records of experience seem to indicate that these other types, such as the harder manganese and aluminum bronzes, are not suitable for this application.

In welding new manganese steel or high carbon steel wear-resistant liners to roller-bearing journal boxes (Fig. 8 and 9), or to the pedestal jaws of Diesel locomotive trucks (or to car trucks), the use of a 25–20 stain-

less-steel electrode has been common practice in the past. More recently there has been a trend toward the use of a mild-steel electrode with a low hydrogen-type coating which apparently is giving entirely satisfactory results at considerably less cost for electrodes. Further, the low hydrogen content weld metal is more easily removed by chipping, grinding, oxyacetylene gouging or arc cutting, during subsequent liner replacements.

Although the high-tensile strength and hardness of the liner plates, themselves, seems to have suggested to some reclamation departments that a high-tensile strength weld metal of high hardability, as well as low hydrogen content, should be used for this operation there is no apparent justification for incurring the additional cost of some 20% for these electrodes over the cost of the mild steel low hydrogen type. Since the weld metal is deposited as fillet welds merely to attach the liners, the weld metal, itself, is not subjected to wear; so ductility rather than high hardness would be desirable for the weld metal.

In Fig. 8, it should be noted that a covering of some kind is provided to protect the precision parts of the bearing from damage by spatter during the welding.

In connection with the depositing of lead bronze, it should be mentioned that this has been done to a limited extent for restoring lateral-bearing surfaces of traction motor support bearings. After the motor has been completely stripped of windings, armature and other electrical parts, the motor case is set on one end, submerged in water almost up to the end of the collar of the bearing, to keep the rotating bearing part cool while the thrust part is being built up with lead bronze.

Fig. 8 Arc welding new wear-resistant liners to roller-bearing journal boxes, while precision parts of the bearing are covered to protect them from spatter

Fig. 9 Roller-bearing journal boxes with new wear-resistant liners welded in place

However, if the bore or rotating bearing part is badly worn, the entire bearing would be replaced rather than reclaiming the thrust part.

Another operation of reclaiming parts of bearing assemblies is that for traction-motor armature bearing housings, including the commutator-end bearing housing and the pinion-end housing, which work out of shape due to impact, and therefore must be rebuilt and machined to bring them back to standard. A departure of 0.003 in. or more from standard dimensions causes trouble with the armature shaft. These steel housings are rebuilt with an arc-welded deposit of mild steel.

DIESEL ENGINE VALVES

Oxyacetylene welding with a low-carbon chromium-cobalt-tungsten, nonferrous alloy (Fig. 10), has proved to be the most satisfactory process for rebuilding the seats of Diesel valves, and this process is used universally. Service records continue to show that such reclaimed valves give 3 to $3^1/_2$ times the service life of a new valve. Several railroads have proposed to hard-face new valves in this manner, before they go into service, because the use of such reclaimed valves has been found to cause no greater rate of wear on the seats in the cylinder head. In fact, the experience of some railroads is that with the use of reclaimed valves, the

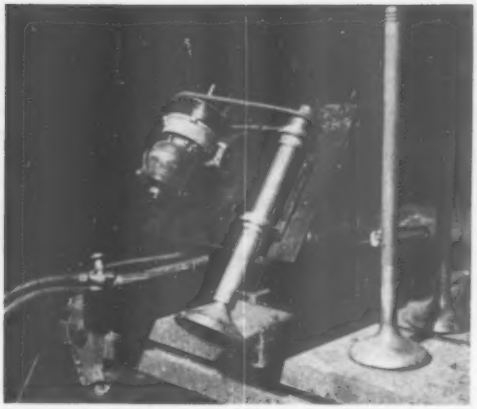

Fig. 10 Diesel valve (with a groove cut in seat on a lathe) mounted on a simple powered positioner for hard facing

On right is a finished valve as-welded

seats in the head require only grinding in, whereas previously they had required reseating, because of damage that had been caused by worn or distorted valve seats. As a result, these railroads now rebuilt all valves by this welding process at the time of first removal of heads for inspection.

A saving of 50% or more in cost has been reported for the reclaiming of these valves, as compared with the cost of new ones.

It is very important that valves to be reclaimed be inspected properly and carefully for cracks before welding. If such cracks exist they can result in serious failures which are sometimes improperly blamed upon the welding. When valve stems are badly worn, they may be turned down in a lathe and then built up with 0.80 carbon steel by metallizing (Fig. 11), after which they are finished by grinding to standard dimensions, thus making the reclaiming of the valve seats worth while.

REPAIR OF ENGINE BASES, FRAMES AND BODIES

In repairing heavy cast-iron structural parts such as engine bases, the general practice is much the same as in the repair of heavy cast-iron parts such as frames of steam locomotives. Braze welding with an oxyacetylene torch has been found to be the most economical process that will afford reliable performance under the usual service conditions and temperatures for such structural parts.

The braze-welding procedure and technique are relatively simple, as compared with gas welding with a cast-iron rod, and therefore braze welding is less critical in application. It has the further important general advantage that a part may often be braze welded, using local preheat, without removing it, whereas gas welding with a cast-iron rod would require that the part be removed for preheating, welding and subsequent slow cooling in a furnace of some kind.

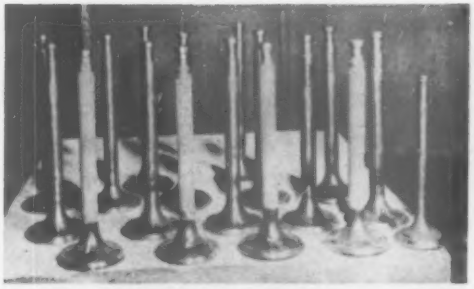

Fig. 11 Diesel engine valves of various sizes which have been reclaimed by hard facing

The four in the first row have had stems built up by metal spraying, and are ready for finishing. Combining of these two operations permits efficient salvage of valves worn on both stem and seat

Fig. 12 Repaired Diesel engine base after removal from furnace following post-weld heat treatment to provide slow cooling

Fig. 13 Close-up of the completed weld on the side of a fractured engine base like that shown in Fig. 12

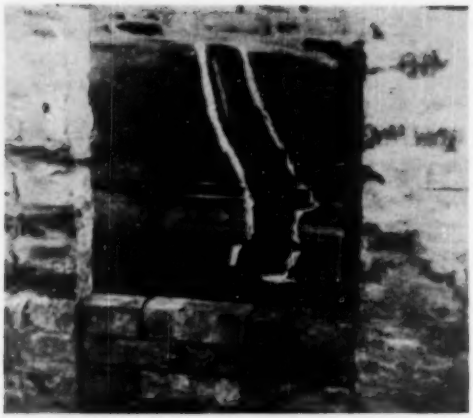

Fig. 14 Broken Diesel engine base (Figs. 12 and 13) in a preheat furnace

Break, outlined in chalk, is beveled and ready for brazing

A cast-iron Diesel engine base with a fracture repaired by braze welding is shown in Fig. 12, and a close up of the completed weld is shown in Fig. 13.

In this case a furnace (Fig. 14) was built around the entire base (to preheat to 900° F. with a charcoal fire) and the additional cost of using a cast-iron welding rod with suitable procedure and preheat would not have been as great as it is in many other cases. However, control of the welding operations would have been more critical, and more time would have been required. The physical properties of the braze-welded joint proved to be adequate for the service conditions.

For the repair of damaged steel side frames, underframes, sheeting and other steel body parts, arc welding with ordinary mild-steel electrodes is usually the most suitable and most economical process to use. However, at points where heavy material must be welded under a considerable amount of restraint against weld shrinkage, electrodes with coatings that produce low-hydrogen content weld metal can sometimes be used to good advantage.

Mild-steel electrodes of Class E6010 or E6012, would be used ordinarily, except in some cases where a butt weld (groove weld) has to develop the full tensile strength of comparatively thick parts of high-strength low-alloy steel. For such cases the use of Class E7010 or E7011 electrodes is frequently recommended. However, it is well to recognize that fillet welds of minimum practical size, made with the less expensive mild-steel electrodes, often will be adequate for the strength requirements. Also, butt welds in thinner material usually pick up enough strength from the low-alloy base metal, to give them adequate strength. When welding must be done at rather low temperatures or with a considerable amount of restraint against weld shrinkage, the use of electrodes that provide a mild steel deposit, such as Classes E6010, E6012 or E6016, facilitates control to prevent cracking, as compared with the use of the E7010 to E7011 electrodes.

In most cases of repairs of this kind, the reclamation of the parts can be carried out at a fraction of the cost of replacement, at the same time saving the cost of delays in waiting for replacement parts which are not often available.

MISCELLANEOUS ITEMS OF RECLAMATION WORK

As the railroads have become more familiar with Diesel locomotive maintenance problems, applications of welding and the oxyacetylene cutting processes have been expanded continuously to include not only the reclamation of major parts such as have been discussed, but also to include many minor items of routine work. Typical of these items are the use of arc welding with a low-alloy chromium-manganese type of electrode to hard face Diesel brakeheads, the use of silver soldering to repair radiators and copper or brass tubing of oil and water lines, the use of a straight-head cutting torch for the removal of pinion gears from Diesel motors when nondestructive methods fail; and various other uses of these processes, some of which were listed in the previous article on this subject which has been mentioned.

The reclamation of Diesel locomotive parts is continually opening up new profitable fields of application for most of the arc welding and oxyacetylene processes. It is especially interesting to note the ever-increasing applications that are being developed for the inert-gas-shielded arc-welding processes, including the newer metal-arc process with consumable filler-wire electrode, as well as the tungsten-electrode process.

Many railroads are proceeding continually on their own initiative, trying out new applications. Some of these are technically sound, and after practical details have been worked out, such applications are approved for standard use. However, some applications have been tried out which were found to be inherently unsuitable for the materials or the service conditions involved. The organization of special Diesel locomotive reclamation departments with experienced supervision, as mentioned at the beginning of this paper, would go a long way toward improving the effectiveness of such efforts to develop new applications as well as improving the general efficiency of Diesel locomotive maintenance operations.

Electronic Control of Production Flamatic Hardening

New developments are described for production flame hardening parts including electronic temperature control of the surface and depth control of hardening by proper combination of variables. Examples are given

by Milton Garvin and David Strauchen

THE heat treatment of metal parts has always been of real interest to designers, engineers and manufacturers who have had to solve the complex problem of correct thermal treatment. Heat engineering applied in a metallurgical sense has made very important strides in the past ten years as more of the facts become known and as means are developed chemically, thermally and mechanically to more closely control the process of heat treatment.

In the past, with the equipment available, in almost every instance, it was necessary to treat a piece of metal by total thermal immersion, despite the fact that only a portion of it required the necessary hardness. In order to bring only certain surfaces up to full hardness, thus retaining a ductile core, it was necessary to resort to carburizing, a costly method of heat treatment. The part, of course, suffered geometric distortion, thus bringing into play many mechanical quenching fixtures.

Accurate temperature controls of the heating cycle and much skill and experience are necessary to successfully heat treat parts. These conditions imposed limitations in the mechanical design of parts and thus in the function of the mechanisms themselves, and it is only natural that the thoughts of metallurgical engineers should turn to a study of high-speed applications of heat to confined areas requiring hardness.

Thus, it came about that we have seen the development of machines to impart intense heat in short intervals of time to localized areas of components requiring hardness only in selected portions.

Nearly a half century ago, the use of acetylene and oxygen suggested itself as a natural heating medium for this operation; but the crudity of application, due to lack of controlled heat, and the high cost of energy placed definite limits on its use. For the same reason propane and natural gases later suffered the same fate of limited application. Although the economy of natural gas was recognized, there was then lack of machines and controls for heat treating available for selective surface hardening.

With the proper equipment now available, it is possible to selectively surface harden parts by the use of acetylene, propane, natural gases and possibly liquid fuels later on.

Without proper controls, we may correctly assume that it is not practical to deliver a fixed quantity of gas to a part in a fixed time cycle and expect uniformity of results when in some instances it is required that an area be heated at the rate of 500° per second, as is now being done.

Selective surface hardening with high-temperature flames involves two basic problems: To confine the heat to the portion of the work to be hardened, and to control within narrow limits the exact temperature to which the area is heated. To maintain the desired hardness pattern, the heat cycle must be rapid—usually a matter of seconds. Thus, the need for temperature control is very critical.

Recognizing this problem, our metallurgical engineers developed the Cincinnati Flamatic Hardening Machine with intense high-temperature flames and electronic control of the workpiece temperature.

Thus, the one element that should not vary—surface temperature—is accurately measured and controlled. Since radiation is directly proportional to the true temperature, a sensitive thermopile, focused on the work, is used on the Flamatic to control accurately and instantaneously the heating cycle, which is so rapid in some cases that surface temperature can be raised 500° in one second. No human eye can work as closely as this new electronic device which controls the surface

Fig. 1 Flame hardening of automotive torque convertor cam ring

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temperature for a few parts or for thousands. Uniformity is now possible and augurs well for gas applications of the future.

This new concept in the process of selective surface hardening of parts lends itself to the development of new types of surface hardening machines, which parallel machine tools in design and utility. They are easily set up into production lines, thus obviating the moving of parts to and from an isolated Hardening Room, plus assuring continuous production of parts, rather than intermittent operation. As development progresses, the use of these machines on many parts will be assured because of economy in operation.

Until the advent of selective surface hardening, the problem of obtaining a hard surface and a soft ductile core was solved by carburizing and subsequent heat treating of usually low-carbon steel. Metallurgically, this was quite satisfactory, but the increased cost of this treatment was high when compared to the more modern methods of selective surface hardening. Consequently, there is an ever-increasing trend toward this type of equipment and operation, with its possibility of higher production, very much lower capital investment, less labor and maintenance costs and comparatively small shop area requirements.

Operating costs are reduced, due to the ease of handling the workpieces, and, in many instances, a less expensive grade of steel can be used, since distortion is held at a minimum by selective surface hardening methods. In addition, preliminary and subsequent operations are sometimes eliminated, and the number of scrapped parts is reduced considerably.

Certain variables are involved when hardening with high-speed gas machines. The depth of case depends upon the type of gas used, the pressure of gas and oxygen, the distance between the burners and the work, the speed of rotation of the work, the time delay before quenching, the time of heating and the temperature of the workpiece surface.

These factors, except the surface temperature, can be varied in several combinations to give the exact heat treatment desired. When acetylene is mixed with oxygen in the approximate ratio of 1 to 1, a neutral flame of about 5600° F. is obtained. Flame temperatures can be increased to 6200° F., and surface temperatures can be raised as much as 500° per second. Gas consumption varies with the size of the workpiece, and the depth to be hardened. For hardening 1 sq. in. of steel to a depth of approximately $^1/_8$ in., about 0.10 ft. of acetylene is required. When propane is used as a fuel gas, it is mixed with oxygen in the ratio of 1 to $2^1/_2$. Propane has a higher heat value in Btu per cubic foot than acetylene, but provides a lower flame temperature when mixed with oxygen.

Fig. 2 Special burners produce 140 hubs per hour

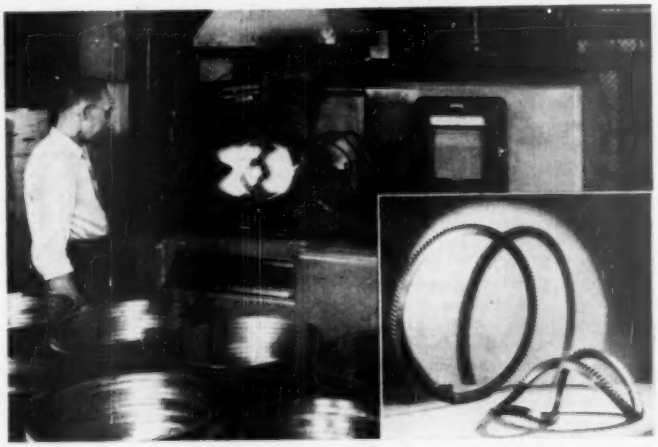

Fig. 3 Thousands of starter ring gears a day hardened with minimum distortion

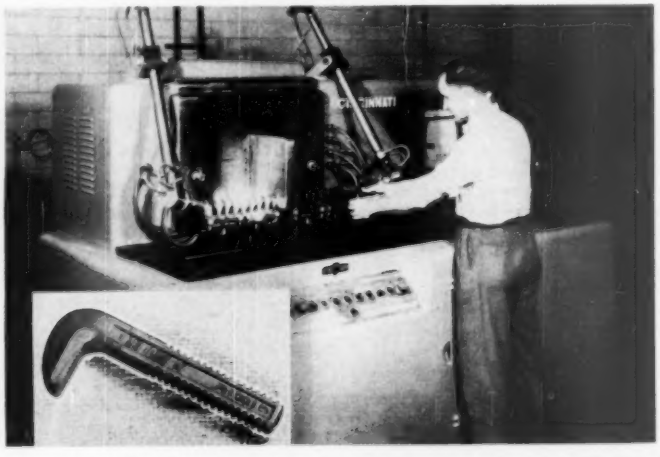

Fig. 4 A special dual station machine for hardening wrench jaws eight at a time

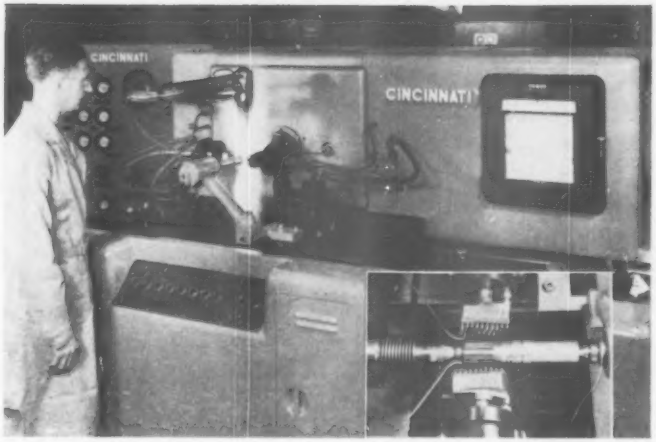

Fig. 5 Multiple diameters of a drive shaft are hardened simultaneously on this machine

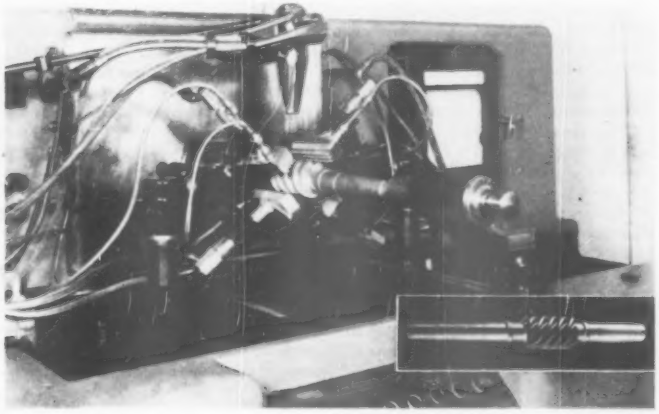

Fig. 6 A worm shaft 27½ in. long is hardened in 40 sec.

Any type of hardenable carbon or alloy steel, including some stainless steel and cast iron, can be flame hardened. Fine grain steel with a carbon content of from 0.35 to 0.65% generally produces the best results with this method of hardening. Parts to be hardened should be clean and free from scale to prevent the formation of soft spots. Hardnesses of as high as about 60 Rockwell "C" have been obtained in flame hardening Meehanite castings, compared with a maximum hardness of about 50 Rockwell "C" obtained with previous methods.

Optimum hardness can be produced on the specified surfaces of the part without affecting the core. Below the hardened surface is a transition zone where the hardness is gradually reduced until the core hardness is reached. By adjusting the rate of heat input, the depth of the fully hard and transition zones can be varied.

It is important, from a metallurgical standpoint, to note that, by this method, between the hard and soft zones no band exists which is softer than the base metal. Since the flames can be directed to localized areas, usually any surfaces on the part can be selectively hardened. Minimum scaling and no pitting are encountered with this process, and any single discoloration can be removed by sandblasting.

Figure 1 illustrates a setup for hardening cam rings for an automatic torque convertor type transmission in a popular automobile. The cam ring has eight internal recesses, the inclined cam surfaces of which must be hardened while leaving the adjacent areas soft. Hardness must be sufficient to withstand the high pressure of overriding clutch rollers, but holes drilled at right angles near the lobes require high ductility to prevent cracking of the surface.

Formerly, these rings were hardened on three selective surface-hardening machines. Two lobes only were hardened at a

Fig. 7 Two flame-hardening machines selectively harden more than 50 different parts

time, making it necessary to index the ring four times. Two men operated the three machines, securing a production of 67 rings per hour with a large percentage of rejects. One flame-hardening machine, requiring one operator, now produces 200 cams per hour, with virtually no rejects. Heating time ranges from 9 to 10 sec. Loading requires 3 sec.; hence, the total time of the cycle is 13 sec.

Gas supply for the machine comes from outdoor tanks, one stationary tank holding 1000 gal. of propane and two trailer units carrying 20,000 cu. ft. of oxygen each. It requires about $^1/_4$ cu. ft. of propane and $^3/_4$ cu. ft. of oxygen per ring. The ratio of one part propane to three parts oxygen produces a slightly reducing flame so that no scale results.

Another part for a torque convertor transmission which is selectively hardened by high-temperature flames is the SAE 4150 hub, shown in the process of heat treatment in Fig. 2.

Special burners designed for this job heat two areas of different diameters so that a hardness of Rockwell "C" 60 is obtained, while distortion is held to a very low value. This method produces over 140 parts per hour—faster by far than the previous method—while the unit cost is considerably less.

Starter ring gears are hardened on machines such as the one illustrated in Fig. 3 at the rate of 300 per hour. These gears of C-1050 forging bar quality fine-grain steel attain a hardness of 55 to 60 Rockwell "C" at the pitch line, while the core remains soft enough to twist into a figure eight without producing cracks. On this critical job, flatness is held consistently within 0.005 in. and roundness within 0.003 in.

Acetylene and oxygen are used in a ratio of 1 to 1. No subsequent operation is required on the gears.

One of the most interesting applications of flame hardening is pictured in Fig. 4.

The teeth of 8-pipe wrench jaws are hardened at a time in 20 sec. on this dual station machine. Twelve hundred parts per hour are flame hardened to 56–58 Rockwell "C" at the cost of 0.4 cent per wrench jaw.

A propane-oxygen gas mixture is used, and the wrenches are automatically quenched in oil. Processing costs are substantially lower than for jaws with hardened inserts.

Figure 5 is a good example of hardened multiple diameters. The pilot end (O.D. $^{51}/_{64}$ in.) and splined section (O.D. $1^1/_2$ in.) of SAE-4140 steel drive shafts for gear reduction units are selectively hardened simultaneously with this installation. The surfaces to be hardened are heated to 1560° F. in 12 sec. A hardness of 50 Rockwell "C" is obtained with negligible distortion. The flame-hardened surfaces require no subsequent machining or cleaning. A production rate of 200 shafts per hour is obtained at a cost considerably less than by the previous method.

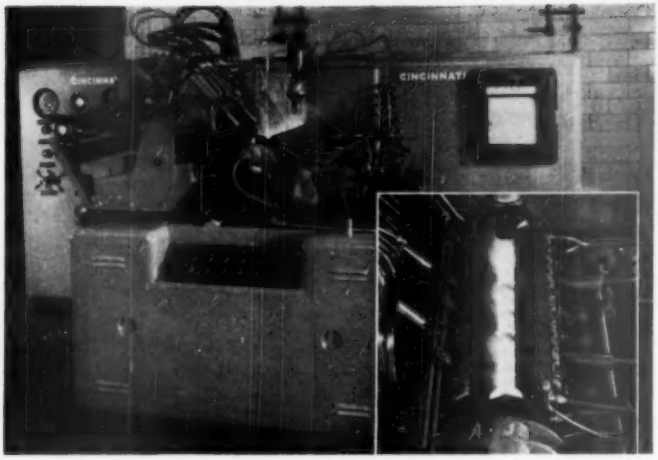

Fig. 8 All twelve cams and eccentric are selectively hardened automatically at the rate of 100 camshafts per hour

The $27^1/_2$-in. worm shaft, shown set up in the machinine in Fig. 6, was previously case carburized. The case on several diameters was machined off, then furnace hardened, and finally shaft ends annealed prior to machining threads and keyways. With the present setup, the shafts are carburized to a depth of 0.046 in. and the threaded section flame hardened to 60 Rockwell "C." The hardening operation is completed in 40 sec. with less than 0.002 distortion and no rejects. Two operations are eliminated and a better product obtained at lower unit cost.

Hook rollers, 5 in. O.D., of AISI-8750 steel tubing are produced at the rate of 30 per hour on the machine shown at the left in Fig. 7. Hardness of Rockwell "C" 60 is obtained 0.040 in. deep, while distortion is so low that no machining is required after heat treatment. The hardness decreases gradually to the base metal hardness at a depth of approximately 0.320 in. and then levels out at the hardness of the base structure.

The machine at the right in Fig. 7 is hardening a 4 D.P. gear 17 in. in diameter and $2^1/_2$-in. face. The teeth on this gear are flame hardened at Rockwell "C" 50 in 6 min. Service life of these gears is increased 50% by this new method of selective surface hardening.

Incidentally, these two machines handle over 50 different parts used by a prominent manufacturer of cranes and shovels.

Six-cylinder automobile camshafts are hardened on four flame-hardening machines, like the one shown in Fig. 8. These shafts are sand cast from high-alloy electric furnace iron, then sandblasted, centered, straightened and flame hardened before being machined. A $^1/_8$-in. case hardness Rockwell "C" 50 is produced around the entire periphery of the 12 cams and eccentric of the shaft. The four bearings and helical gears are left soft for subsequent machining.

The entire heat treating operation takes approximately 30 sec per shaft, and each machine averages better than 100 shafts per hour. These machines operate on a fully automatic cycle. The operator merely loads shafts on the rails at the left. Approximately 4 cu. ft. of propane and 12 cu. ft. of oxygen are necessary to heat this shaft.

The metallurgical structure of the hardened iron is quite uniform, the only difference being caused by variations in the combined carbon and alloy content of the iron. Distortion is at a minimum with some shafts requiring straightening after selectively flame hardening.

The ability to reproduce hardness patterns by selective surface hardening with high temperature flames depends to a

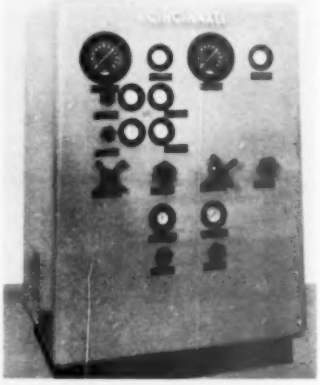

Fig. 9 A high degree of control can be obtained by careful regulation of gases

Fig. 10 Flame-hardening machines are now being produced in quantity by assembly line methods

great extent upon the degree of regulation of the gases. To achieve this, it is necessary to meter the gases carefully.

Figure 9 shows a gas regulating cabinet of the type usually employed. Oxygen is passed through a diaphragm regulator, and then metered through standard orifices. The fuel gas is passed through a safety flash arrester and a diaphragm regulator before going to the machine. Needle valves in the lines to each torch facilitate the regulation and control of the flames so maximum heat may be obtained, and the atmospheric conditions surrounding the work will be nonscaling.

It is evident from the previous analysis that the use of high temperature flames as a method of selective surface hardening is becoming an important factor in the heat-treating industry.

The production line pictured in Fig. 10 shows that flame-hardening machines are being produced in ever-increasing quantities. Manufacturers of parts, ranging from small calculating machine gears to large Diesel crankshafts, are finding that flame hardening is the answer to many of their heat-treating problems. The substantial reduction of costs and increased production obtained with this method are reasons enough for this trend, and the ability to produce a better product without a large number of rejects clinches the case for selective hardening with high-temperature gas flames.

Use of Oxyacetylene Process to Reduce Stress

Residual stresses and conditions under which they may become dangerous are discussed as well as methods for alleviating this danger

by Harry E. Kennedy

BEFORE discussing the relief of residual stress let me refresh your memories as to what residual stresses are and how they are developed. Imagine a long butt weld joining two fairly wide plates. Let two saw cuts parallel to the weld, 1 in. apart on either side of the weld, remove the entire weld. When the separation has been completed the weld metal will have shortened by about 0.0015 in. per inch of weld. It will require approximately 40,000 lb. per square inch of cross section to stretch it to the length it occupied in place. It is therefore obvious that the weld was under a corresponding strain before it was removed from the plate.

To understand how this tension is produced let us refer to the 3-legged model shown in Fig. 1. Let the center member be heated while the outer members remain at room temperature. The heated material will expand against the two crossheads which, in turn, will transfer tension loads to the cold members. For every degree centigrade the heated member exceeds the nonheated member a compressive stress of about 350 psi. will develop, assuming the material to be mild steel.

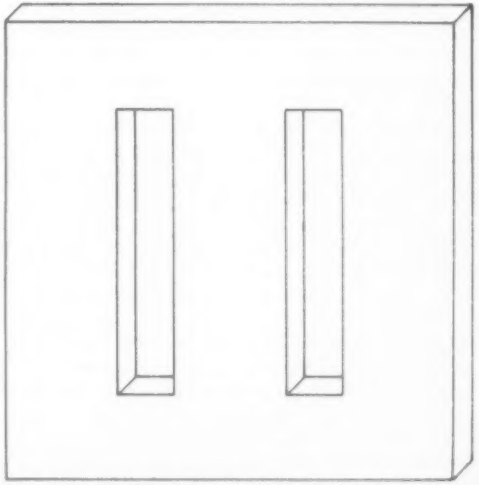

Fig. 1 Three-legged type of specimen in which a high-residual tensile stress can be induced by local heating

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Presented before the Annual Meeting of the International Acetylene Assn., San Francisco, March 27–29, 1950.

A hundred degree rise would bring about a stress of 35,000 psi. If the assembly is permitted to cool, the stresses in all 3 members will decrease and become zero when the temperature becomes equal in the 3 members. If the heating had been continued so that the center member reached say, 500°, upsetting or thickening of that member would have resulted because the yield point of the material would have been exceeded. If after such heating we permit the assembly to cool, the center member must stretch because it has permanently shortened during the heating. The stretching will tend to decrease the upset which came about while heating. The tension stress will be at 40,000 psi. and remain at that value when all three members reach the same temperature.

The difficulty of visualizing the stresses can be lessened by isolating the stresses in 3 individual members. The state of stress would have been practically the same had the heating been confined to a narrow zone along the center line of a wide plate, as in a weld. The upsetting would have occurred during the heating, so that on cooling a tensile stress will exist in the weld area. This is a residual stress. In actual welds the stress is a maximum in the center line of the weld. It decreases to zero about 3 in. from the center line of the weld. The remainder of the plate is in compression as in the two outer legs of the model. In wide plates the compressive stresses will be very low because the cross section sustaining the stress is large. Figure 2 is a sketch showing the distribution of longitudinal residual stress in a welded plate.

Referring again to our model with its center member under the tensile stress, suppose we place it in a furnace and heat it to 1200° F. At this temperature the steel is unable to support but a slight stress. Upon cooling, there will remain only an insignificant stress in any of the members. This, of course, is the commonly practiced furnace stress relief. We could grip the assembly in the jaws of a testing machine and so apply sufficient tension to stretch the center member by the amount of its length deficiency. This is an example of a less common practice of overstressing a vessel hydraulically to effect stress relief.

Some years ago I suggested a third method of reducing stress and one with which this paper is principally concerned. If the two outer legs in our model are heated while the center remains cold, they will expand and through the cross heads subject the center member to tension. Only a slight force is necessary to elongate it permanently because the center member has yield point stress at the outset. If the temperature of the outside legs is limited to a proper value their expansion will be just sufficient to stretch the center member by the amount of its length deficiency. Upon cooling, the assembly will be without stress so that if the center member were sawed in two the width of the saw kerf would exactly equal the width of the saw.

Again the illustration may be applied to a weld in a plate. In practice, welding stresses of 40 or 45,000 psi. may be reduced to negligible values by running

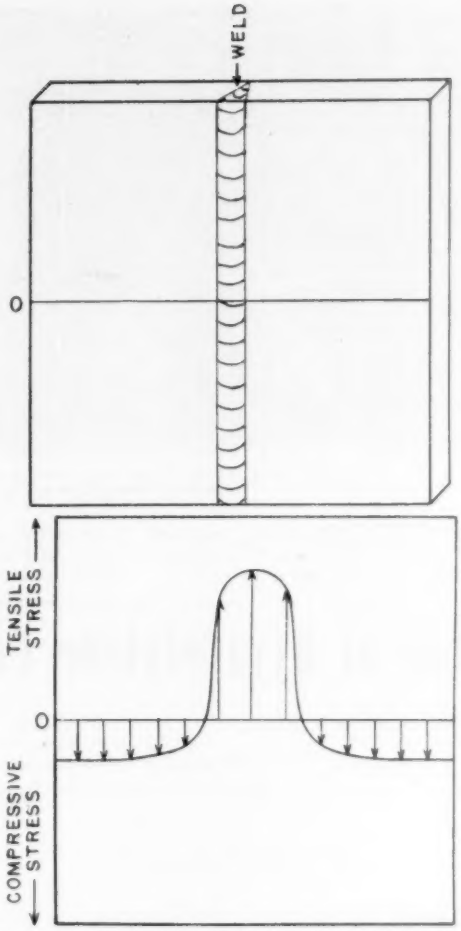

Fig. 2 Sketch showing distribution of residual longitudinal stress in welded plate

oxyacetylene torches on either side of the weld at such a speed that the plate metal is raised to 350°. The heated area should be 6 in. wide. The operation is accomplished at about 18 in. a minute.

Greater efficiency in stretching the weld metal and avoidance of disortion results by cooling the plates by a water spray following the heating. The operation is not critical. A slightly higher temperature than 350° merely puts the weld in mild compression. Plate temperature should be checked by temperature indicating crayons. Once suitable operating conditions are arrived at, controlled motor-driven torches maintain constant temperature. After the operation, the weld will be without stress. Because the temperature of the heated area is limited to 350°, no permanent upset occurs in these members; therefore no secondary stresses are produced in this area. The two heated

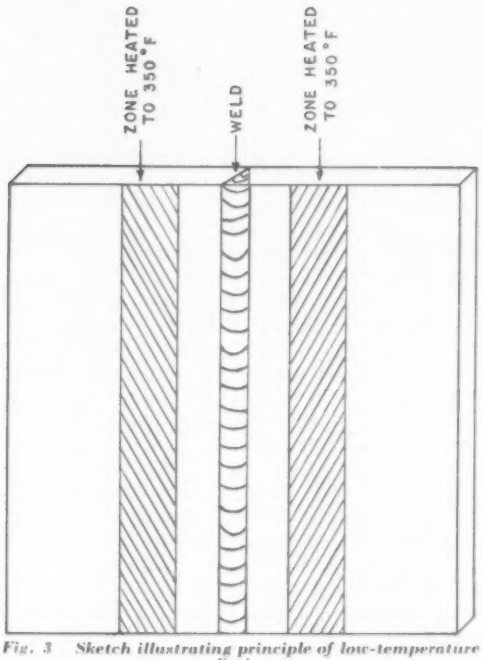

Fig. 3 Sketch illustrating principle of low-temperature stress-relieving process

Weld zone is forced to elongate permanently when shaded areas parallel to weld are heated about 350° F. hotter than weld zone

sections behave elastically. The sketch shown in Fig. 3 illustrates this process.

The question arises: does a residual stress do harm? Because if it is harmless, relieving it is only of academic interest. If a material is brittle, such as glass, a residual stress will surely shatter an object of this material at the slightest shock; if the material is reasonably ductile, residual stresses are harmless because as we have seen a very slight amount of plastic flow will redistribute the stresses so that the load stress does not add directly to the residual stress.

That this is true is self-evident. Thousands of welds, each of them—at least originally—with a residual stress of 40,000 psi. perform satisfactorily. Structural shapes invariably contain residual stresses due to unequal cooling.

However, there are certain conditions under which mild steel almost completely loses ductility and becomes brittle. These are the coincidence of low temperature and the presence of a notch or stress raiser and/or metallurgical damage.

Steels vary widely in their susceptibility to notch brittleness. Some are brittle at room temperature, while others retain ductility at extremely low temperature. It is unfortunately true that welding greatly increases the tendency to notch brittleness. When a bar of mild steel with a notch is loaded in a tensile testing machine above the critical temperature, after reaching the yield point the material "necks" down until failure ends the test. If the test is performed at or below a critically low temperature, there will be no evidence of yielding. Instead the plate will fracture with dramatic suddenness. I have measured the speed at which the crack propagates across the plate and found it to be nearly a mile a second. The load at failure, however, is approximately the same for the ductile and nonductile specimens.

If it is true then that a residual stress may add to the load stress, this should manifest itself by a lessened capacity to carry a load. Many tests have failed to show this to be true. Failure to demonstrate the influence of a residual stress on load carrying capacity may be attributed to plastic flow.

T. W. Greene[1] of The Linde Air Products Co., was the first to demonstrate the great benefits of low-temperature stress relief. He contrived a test which consisted of deliberately introducing a flaw in his weldments by a saw cut in the mating edges of the plates to be welded. In his test the plate was supported at opposite ends and loaded at the center as a beam. The weld defect was naturally on the under side. The plate was cooled by dry ice to a predetermined temperature and bent as a beam at this low temperature. The flaw so introduced proved very severe. Fracture took place with little or no deflection. Part of the plates were tested in the as-welded condition, part stress relieved by low temperature and the remainder furnace stress relieved. The plates, with identical welds, were all identical in their defects, the only difference being subsequent to welding. Those in the as-welded condition broke at very small apparent loads—of the order of seven to 10,000 psi. In one instance, failure took place during the cooling, without a load at all.

On the other hand, those plates that were stress relieved failed at loads of 50 to 60,000 psi. The testing conditions were not abnormal. The defect was not more severe than in a weld lacking full penetration or with a hairline crack. The temperatures were not lower than any weldment might be expected to experience, nor is this an unusual application of force. The conditions to which the stress-relieved weld was subjected were abnormal. At −60° F., the stress-relieved plate supported a stress of 56,000 psi. before failure, whereas in the as-welded condition, at +20° F. failure took place at 16,000 psi.

The greater the retained ductility the less hazardous are the residual stresses. Preheating is very effective in retaining the original ductility.

A series of tests illustrate this very simply. I ran a standardized weld bead on identical specimens, with different degrees of preheat from zero to 600°. In a notched cold bend test the bend angle varied from zero to 45°. Preheating to 250° is simple and effective. If the finished weld is then stress relieved, every safeguard to the weldment has been taken. If furnace stress relief is possible, an additional benefit will result—ductility will be restored.

So many experiments have been performed indicating that residual stresses are harmless that an explanation

is needed. Most of the tests were tension tests. It is necessary to use a relatively wide plate in order to develop full residual stress. A notch in such a plate is not sufficiently severe to prevent plastic flow. Residual stress is therefore relieved.

When the same plate is bent as a beam, the stress concentration is sufficient because the maximum stress is concentrated at the defect. I have performed these tests and many others in addition. When a cold bend test is made on a wide plate under conditions of impaired ductility, the crack originating in the defect usually extends across the tension zone. Complete failure follows by a further application of load. Referring again to our 3-legged model, the stress in the center member is not generally referred to as a residual stress. When the tension and compressive zones are not interlocked the stress is referred to as a reaction stress. If the center leg is notched and cooled so as to induce brittleness, this set up is particularly vulnerable to stresses set up by the welding. I have failed dozens of such specimens without the application of any external load. After stress relieving by heating the outer legs of the model, failure does not occur under equal conditions.

In order further to elaborate this work, I undertook a series of tests wherein no welds were involved. Plates 18 in. wide by 24 in. long, varying in thickness from $^{3}/_{4}$ to $1^{1}/_{2}$ in., were notched by sinking a $^{1}/_{32}$-in. milling cutter $^{3}/_{16}$ in. below the surface of the plate. The location of the cut was at the center of the plate and at right angles to its major axis. Two heating torches applied heat to opposite faces of the plate. The heated area was confined to a strip simulating a weld along the major axis of the plate. The temperature of the plate was limited to 700° F. in order to avoid metallurgical damage.

Four pairs of plates, in thicknesses of $^{3}/_{4}$, 1, $1^{1}/_{4}$ and $1^{1}/_{2}$ in. were thus treated. Each plate was therefore left with a residual tension stress, comparable with a weld stress but without metallurgical damage. One of each of the pairs was stress relieved in the following manner: a channel directed stress of cold water over the stressed area. Two heating torches heated the areas outside the tension zone in order to extend and relieve the tension zone. When these were tested, that is, a plate with stress against one without stress, in every instance the stress-relieved plate sustained a greater load than the plate without stress relief.

The thicker the plate for comparable steels, the more important is the effect of residual stress. There is greater restraint in thick plates and the notch is further from the neutral axis. The embrittling effect of the weld was absent in these tests, so considerable ductility always remained even at very low temperature—nevertheless the average load in the plates with a residual stress was only 70% of the plates that had been stress relieved.

In these tests, a copious stream of water prevented any appreciable heat treating effect by the heating torches, so that the improvement in performance must be attributed to the relief of stress. If there is an increase in notch toughness due to heat diffused into the weld and Flanigan[3] has shown that storage at 250° F. does this, it is a much desired auxiliary benefit.

It may not be self evident that this method of stress relief is applicable to intersecting welds, plug welds or T-sections. All these more complex stress patterns have been effectively relaxed by this method. It is necessary only to remember that for every tension stress there must be a corresponding compressive stress. Controlled heating of the area containing the compressive stress will relieve the tension stress.[2]

The Sun Shipbuilding and Dry Dock Co. have consistently low temperature stress relieved their ships. One of the largest gas holders ever built has been thus treated.

Too many welded structures have failed for us to ignore any safeguard that may be taken to prevent such failures. When less was known of the cause of these failures it was common practice to place the entire blame on residual stress. This proved erroneous. Design is certainly the most important factor for insuring safety, but it is equally wrong to assume that residual stress may never produce failure. There are too many authenticated cases, wherein completely unloaded objects have cracked during a cold night, to ignore them. Ships have failed at calculated stresses of less than 10,000 psi. It is difficult to conceive that a residual stress has not contributed to such a failure. Preheating and stress relief are not spectacular operations, but neither is a smallpox vaccination.

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Automatic Welding in Steel Mill Maintenance

Automatic welding in steel maintenance turns out more work, increases flexibility, enlarges the scope of maintenance work, minimizes shutdown time and reduces costs

by William P. Hoffman

THE Mechanical Department of Wisconsin Steel Works is not only responsible for the maintenance of equipment in the plant but also performs new construction work. Steel mill equipment is usually massive, costly, and perhaps of even greater importance from the maintenance angle, part of an "assembly" line whose down-time cost may run into hundreds of dollars per hour. Under the severe operating conditions imposed, wear on machinery is terrific and one basic maintenance problem is the rapid and economical replacement of worn parts.

Normal hand-welding procedures for build-up work and new construction have been utilized for some time, but realizing the limitations imposed by high material and labor costs, we have been quick to adopt more efficient ideas and equipment that allow us to extend the scope of welding applications. The welding shop was in need of a welding process which would turn out more work, cut down the backlog of jobs, give more flexibility in the application of welding to the work and which, by increasing output, would cut costs. After considerable study, an automatic welder of the submerged-arc type was chosen as the one that would be of most value. On June 1, 1949, one was purchased and installed in the shop.

EQUIPMENT

Considerable thought was given to the problem of mounting the automatic welder on a machine or fixture that would take care of the varied types of welding jobs encountered. We wanted one setup to do rotating or straight-line welding, and the mounting shown in Fig. 1 provides just that.

If the piece to be welded can be rotated, it is placed on the turning rolls which will handle diameters to 6 ft. The track for the self-propelled carriage is mounted on two columns and may be raised or lowered mechanically.

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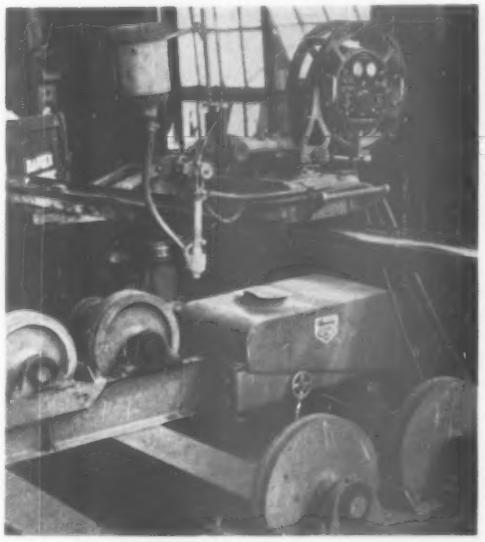

Fig. 1 Setup of automatic welder

To do straight-line welding or flat surface build-up work, the turning rolls can be easily moved to one side, or the track can be extended beyond the turning rolls to reach the piece to be welded. The length of track for the carriage is 20 ft., and it can be raised or lowered 5 ft.

A lathe was remodeled to adapt it for use with an automatic welding head. The lathe is 22 in. over carriage, 30 in. over ways, with the 12 ft. carriage driven by a lead screw at the rate of $^1/_8$ to $^1/_2$ in. per revolution of work. The head is mounted on the carriage of the lathe. The travel of the carriage can be so accurately adjusted that in many instances the finished weld will be uniform enough to use the part without further machining. All of this equipment, with the exception of the turning rolls and lathe head, was made in the maintenance shop and will take care of almost any maintenance welding job encountered.

A more or less detailed description of some of the work done with this process will give a better idea of the

field of application as well as the possible savings in time and cost. The rebuilding of table rolls is a typical example. Table rolls are used to convey ingots, billets or bars to the mill rolls and from one set of rolls to the next. They vary in size and weight from 12 in. diameter, 4 ft. long, weighing about 800 lb. up to 18 in. diameter, 10 ft. long, and weighing about 3500 lb. Some rolls are subject to intense heat, water, salt and scale and, in many cases, operate 24-hr. a day. Under these conditions, it is not at all surprising to receive the roll with the barrel and journals in an extremely worn condition. This wear is not always uniform as one section of the barrel or journal may receive much more wear than another. If this is the case, the badly worn sections are filled in separately before the general build up.

Fig. 2 Journal of blooming mill table roll being built up by automatic welding

Figure 2 shows the journal of a blooming mill table roll being built up by automatic welding. This type of job is simple to set up on the turning rolls, and the worn surface can be quickly brought back to size with a sound deposit of weld metal. In all, 25 lb. of $^1/_8$-in. welding rod was deposited on the surface during the 3-hr. welding time. Other welding conditions are as follows:

Current	A. C. 300 amp.
Voltage	32
Welding speed	12 ipm.
Flux—UM	No. 90, 12 x 200
Electrode analysis	C., 0.65%; Mn., 1.05%

The weld deposit was readily machined to original size.

The shop salvages many blooming mill table rolls that require resurfacing over the whole face. This rebuilding job must be done at regular intervals because maintaining the proper diameter extends roll life by reducing shock loads. The roll shown in Fig. 3 required 700 lb. of weld metal to bring it to proper diameter. Several badly worn sections were treated individually before the three general welding passes were started.

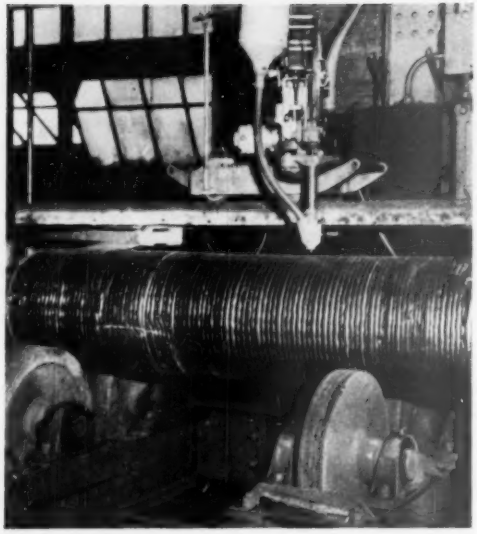

Fig. 3 Blooming mill table roll resurfaced by automatic welding

On this type of application, the table roll may creep on the fixture if the turning rolls are not exactly parallel. This may be easily remedied however, by setting the turning rolls so the creep is always in one direction and then blocking the end of the shaft to prevent movement. Another point to watch is the manipulation of the current after welding has progressed 5 or 6 hr., the build up of heat in the roll may make it necessary to reduce the current to keep the weld metal from running off the roll.

This type of welding can also be done in a lathe setup where such equipment is available. In either case the setup is not difficult and the setup time is short.

Three welding passes, using $^3/_{16}$-in. diameter rod and No. 90, 12 x 200 melt were required for the job. It was done without preheat and as in other instances, the solidified melt came off readily after cooling and so no cleaning was required between passes. Other welding conditions were as follows:

Current	A.C. 550 amp.
Voltage	32-34
Speed	12-14 ipm.

After this roll is given a rough cut in the machine shop, it will be put back into service. It might be added that machining is no problem as the weld metal cuts easily, and no special tools are needed.

Excessive wear on blooming mill or merchant mill table rolls makes hand reclamation costs prohibitive, whereas rebuilding badly worn rolls with automatic welding procedures is economically sound. In this

Fig. 4 Replacement base for 40-in. blooming mill manipulator drive

particular case a new roll costs approximately $500. Rebuilding by hand and machining would run about $800 and resurfacing with submerged-arc welding and machining costs about $325. Obviously, we are in favor of automatic welding.

REPLACEMENT BASE—40-IN. BLOOMING MILL

The replacement base for a 40-in. blooming mill manipulator drive is shown in Fig. 4. The manipulator is the equipment that guides the hot 4- to 5-ton ingot into the 40-in. mill rolls. It also has to push the ingot across the table rolls as the ingot goes from one pass in the rolls to the next. The present manipulator drive has bearings and pinion stands on independent bases that are set in concrete. Some maintenance problems were encountered due to the inability to maintain proper alignment between these independent bases. This new replacement base will be a common base and has been designed to maintain positive alignment which had been impossible previously due to movement created by the shock loads to the manipulator drive with the pinion stands on independent bases.

This base was designed to use our own product, thereby eliminating costly patterns and castings. All slabs were produced in the plant and were fabricated by submerged-arc and manual welding. The submerged-arc welding was used to fabricate the three I-beams, the ends of which can be seen. The beams were made of 2-in. thick slabs, 30 ft. 9 in. long. The entire structure weighs 20 tons.

The slabs were tack welded before using the submerged arc, and these tacks were burned in rather deeply so as not to interfere with the bead put on by the automatic machine. Three passes of fillet-type welds were made on each joint, but after each pass, welding was done on the opposite side to keep the distortion to a minimum. This procedure actually did keep distortion to a very low figure. The three I-beams were then set up and the cross beams and stiffeners welded manually. The major concern here was to keep the top level as any distortion to the bottom did not matter because this base will be set in concrete.

32 IN. MILL MANIPULATOR RAM

You have all probably heard the old nursery rhyme bemoaning the downfall of a kingdom through the loss of a horseshoe nail. The story of the worn manipulator ram shown in Fig. 5, although far from a fairy tale, follows a similar pattern. Two hundred pounds of weld metal saved this 5-ton item from the scrap heap. This ram is a part of the equipment described in the previous section on the replacement base. From constant, hard usage, the surface of the ram became worn to the point where it had to be removed from service.

This job exemplifies the flexibility of the universal welding head and carriage mounting. It can be seen that the turning rolls were removed, the ram set up on blocking and the track moved into position. Also clearly shown is the revolving type of ground that is normally used for rotating work, although in this set-up, it remains stationary. The strips of flat bars along the sides of the ram are tacked on before welding

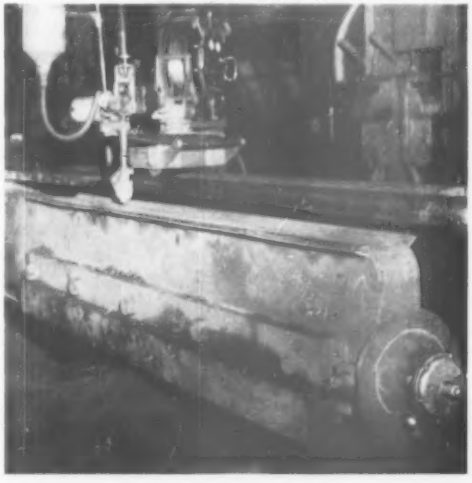

Fig. 5 32-In. mill manipulator ram

Fig. 6 Mill drive spindle

to hold the melt flux and weld metal so that the welded surface does not taper off at the extreme edges. Neither premachining nor preheating were required. Distortion is a problem in this welding job and, so far, we have not been able to eliminate it, but by welding on opposite sides of the ram after each pass, we hold the distortion to a minimum. Further welding information is as follows:

Current	A.C. 450–500 amp.
Voltage	30–32
Welding speed	12–14 ipm.
Electrode	$^{3}/_{16}$
Preheat	None
Weight of metal deposited	125 lb.
Flux	No. 90, 12 x 200
Cleaning between passes	None
Number of passes	2

After welding and machining, this ram was as good as new. The economy in this type of job lies in the fact that weld metal can be laid down 5 to 6 times faster than by manual welding.

MILL DRIVE SPINDLE

A mill-drive spindle such as shown in Fig. 6 transmits the power from a pinion stand to the mill rolls. They are usually made of forged steel, 0.40 to 0.50 carbon, and this particular one was 21 ft. long, 19 in. in diameter and weighed 18 tons. About $^{3}/_{16}$ in. of wear of the cross-hatched bearing areas necessitated removal and rebuilding by submerged melt welding. As in previously mentioned cases, the use of turning rolls minimized setup time as it was only necessary to set the spindle in position with the crane, position the head, and start the build-up operation shown in Fig. 7. Note, particularly, the uniformity of deposit. This not only minimizes the amount of rod required, but of even greater importance, the time required to finish machine the areas.

One hundred and eighty-two pounds of $^{3}/_{16}$-in. welding rod was required for both areas and the melt used was No. 90, 12 x 200. Other welding conditions were as follows:

Current	A.C. 550–600 amp.
Voltage	32–34
Speed	18 ipm.

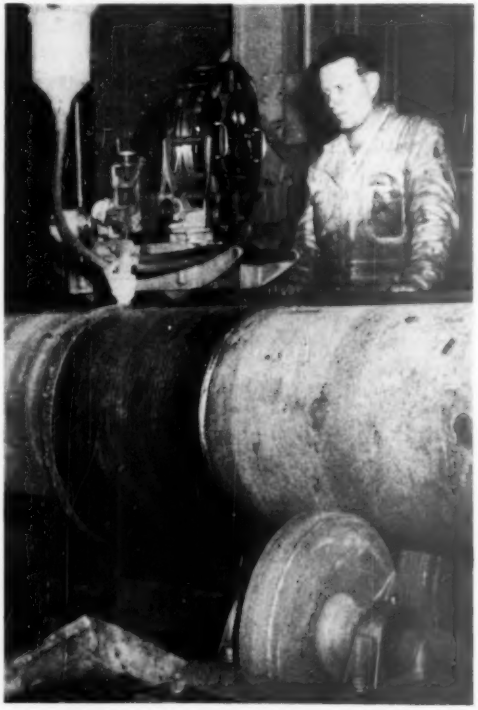

Fig. 7 Mill drive spindle set up for start of build-up operation

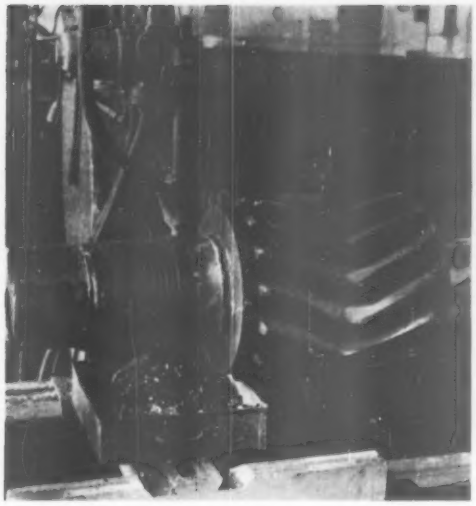

Fig. 8 14-In. herringbone mill pinion

14-IN. MILL PINION

The teeth of the 14-in. herringbone mill pinion shown in Fig. 8 were still in good condition, but excessive wear on the bearing surfaces and wobbler pads put it out of service. Because of the small area involved, the worn wobbler pads were rebuilt by hand welding. Submerged-melt welding was used on the two bearing surfaces. No premachining or preheating were required and, as is generally the case with circular objects of this type, distortion was not a problem.

There were no free circular or cylindrical surfaces for the normal roll drive so the gear was mounted in the lathe-type unit for rebuilding. A total of 150 lb. of rod, deposited in 8 hr., made this valuable item ready for final machining to original size.

Items such as this are usually thickly coated with grease and dirt which must be removed prior to welding

Fig. 9 Setup used to weld wheels and axle journals of stake car

operations to insure sound deposits. Either steam or solvents are satisfactory for the job, but it must be thoroughly done. A few minutes spent on cleaning operations is good insurance of final quality welds.

CAR WHEELS

There are about 175 ingot mold cars, 135 stake cars for transporting billets and slabs and 115 open-hearth pan cars in the mill. The number of wheels and axles replaced each year, with 425 cars in service, is quite high and represents a considerable capital investment. This provided a logical place to attempt cost cutting by using submerged-melt welding for reclamation.

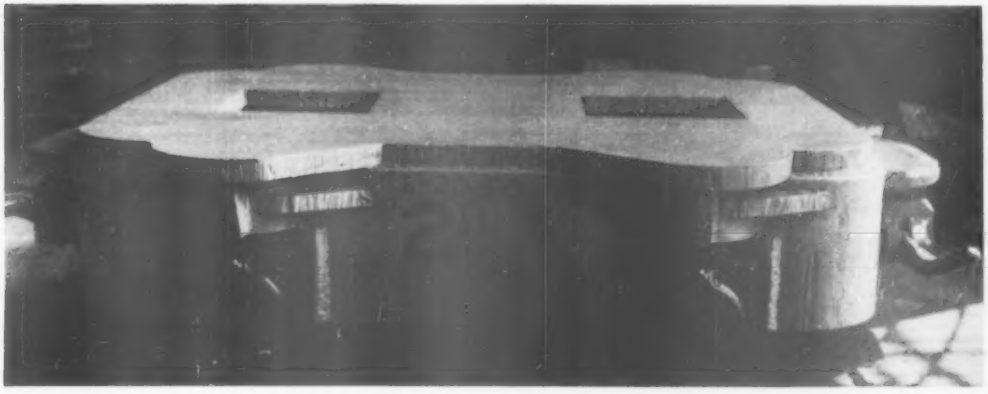

Fig. 10 All-welded ingot mold car

Figure 9 shows the setup used to weld the wheels and axle journals of these cars. The axle and wheels shown are those used in a stake car. The axle is 4 ft. 11½ in. long, journal is 4¼ in. in diameter and the wheels are 18 in. in diameter. These wheels cost $30 each. They can be brought back to size for approximately $15 and to the $15 saving can be added the cost of removing and replacing a new set of wheels on the axle, as welding is accomplished with the wheels in place. If the journals are worn, they are also brought back to size without any change in the setup. The job shown used ⅛-in. electrode, with 350–400 amp. welding current, and 30 v. A rod such as Oxweld type 6150 can be used to obtain a harder deposition which is an advantage in certain similar applications.

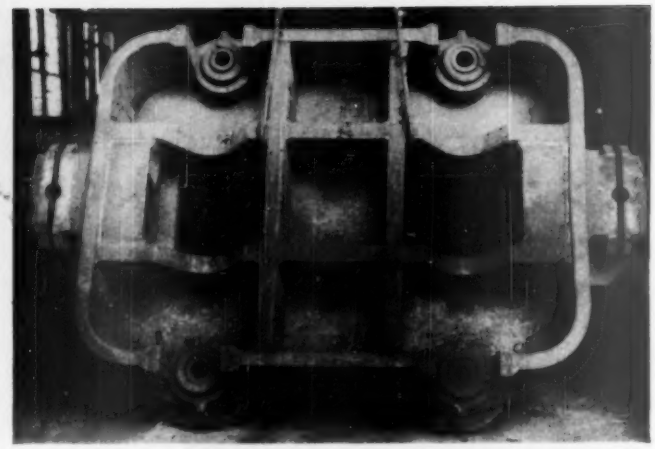

Fig. 11 Underside of ingot mold car

INGOT MOLD CAR

In line with the program to reduce costs and utilize "home-grown" products, the welding shop designed and built the all-welded ingot mold car shown in Fig. 10. The slabs were rolled in the mill and the material was flame cut and fabricated by hand-arc welding. Two of these cars have been fabricated to date and more are in the process of construction. Fabricating the cars has resulted in a substantial saving over the cost of the cast steel cars previously purchased.

This type of fabrication represents an ideal job for the new flexible submerged-melt apparatus, and subsequent cars have been fabricated using this equipment. The main feature of this equipment is that the welding rod and welding composition are automatically fed from the nozzle at the end of a 20-ft. flexible hose. The nozzle piece is held in the operator's hand and can be quickly moved from one work location to another. Another advantage is that it can also be used for making a number of short welds without too much setup time being required.

Figure 11 shows the underside of the ingot mold car. The rib work, bumper blocks and windows are also clearly shown. Approximately 250 lb. of welding rod was used in this job and the total weight of the car is 11,800 lb.

CONCLUSION

In general, the adoption of submerged-melt welding for steel mill maintenance has greatly enlarged the scope of operations of the welding shop and resulted in appreciable savings in mill operation. Through the use of the automatic and semiautomatic submerged-arc welders, we are confident that we can handle almost any job that confronts us. Worn parts of costly machinery formerly good only for scrap, now can be reclaimed at nominal cost. "Hard-to-get" items can be quickly rejuvenated, thus lowering inventory costs and minimizing expensive shutdown time. Machinery can be designed and built to meet a specific need offtimes at costs lower than standard items. In the case of new fabrications, delivery can be of utmost importance.

Advantages of the process for the type of applications described are numerous. High hourly deposition rates are possible without sacrifice of weld quality. All welding rod purchased winds up in the ready-to-machine product and no allowance must be made for spatter and stub loss. Fused melt usually loosens as it cools, thus eliminating slow chipping operations and permitting uninterrupted multipass operations. Deposited metal is sound, soft (if desired) and readily machinable. A wide variety of rod and flux combinations are available to meet virtually all requirements. High heat input not only permits fast welding but also holds distortion to a minimum and, in many cases, welded surfaces are smooth enough for immediate use, thus eliminating machining operations.

Welding of Farm Tractors

Redesigning for welding results in economies in the manufacture of farm tractors. Nearly all processes of welding are employed

by J. Leonard Buchholz

THE following is a presentation given to describe various applications of welding on modern farm tractors. Practically every welding process for steel and grey iron is used in such manufacture, and photographs illustrate actual practices used. Redesign of parts to welded construction is shown along with data to prove that good welding design will bring about production economies.

Welding is a group of manufacturing processes which is rapidly growing in the International Harvester Company, and its use in the production of tractors is one very important phase of the program. I would like to cover, very briefly, the forms of welding we use along with some physical samples and pictures to illustrate our manufacture.

In the earlier model tractors, grey iron and bolted sheet metal were predominant. Constant research has found many ways to improve the joining of steel, and greater use of this metal in the tractor explains why we make more extensive use of welding.

J. Leonard Buchholz is Welding Engineer, Farmall Works, International Harvester Co.

Presented at the Thirty-first Annual Meeting, A.W.S., Chicago, Ill., week of Oct. 22, 1950.

The accompanying picture (Fig. 1) is of our standard "M" tractor and represents a modern machine that requires a great amount of welding to manufacture. Most of the following material is taken from actual case histories relative to producing a tractor of this type.

Farmall production requires many resistance welding machines, arc welders, torch and brazing units, plus some induction and furnace brazing equipment, to produce all the welds on every tractor. A considerable amount of welding is used on forgings and castings in addition to the sheet-steel applications visible in the picture.

In the manufacture of farm tractors, it is our custom, in most cases, to use standard welding machines to weld assemblies instead of special-purpose units that are limited in versatility. To manufacture many different model tractors, we have to maintain a flexible welding program capable of making changes in minimum time and investment. Special tooling is frequently used on standard basic machines; however, if production and economies warrant it, special machines are used.

Note, in Fig. 2, a photo of a different model tractor using a considerable amount of sheet steel practically

Fig. 1 A modern farm tractor requiring many forms of welding to manufacture

Fig. 2 Another model tractor illustrating extensive use of sheet metal adaptable to spot and projection welding

Table 1. Welding Specification Set Up Card for Radiator Brace Tie Plate

68282-D
T.C. 9491

Spot Welder

Part No.	*Ga.*	*No. Spots*	*Operation*	*Fixture*
2-67852-D	0.1644	6	5	J-68282-D-W1
1-68278-D	0.1644	..	Series—M	
1-67850	0.1196	2		

				Test strips	
Heat tap high	1	Air pressure	80	High limit	6500
Squeeze	23	Diameter of spots	2/8	Low limit	5400
Heat	10	Pulsations	3	High	6250 } 250 range
Cool	8	Top tip holder	1 1/2 x 14	Low	6000 }
Weld intervals	40	Top tip	3139		
Hold	9	Bottom tip	3139		
Off	6	Bottom tip holder	4 in. offset		
		Tip space	1 in.		

all fabricated by welding. Spot and projection-welding applications are very evident on fender braces, platform, power take-off guard and numerous brackets. Parts that have to be serviced in the field or removed for specific reasons are attached by bolts and weldnuts.

Both pictures give views of the fuel tank with its seam-welded parts.

When tooling for a new job, skeleton models are built and experimental toolings made to try out both product design and tooling from a manufacturing standpoint. Engineering makes use of these experimental setups, and, thus, the design time in tool engineering is kept to a minimum.

The Welding Engineer makes all original tryouts of tooling and develops a welding specification card. This card (sample shown, Table 1) gives all pertinent information required to set up and run the job. As an example, when a new job is scheduled for spot welding and tooling is made available, the job is tried out, and any change to improve operation of fixture is noted. Sample coupons of same gage stock are spot welded and tested on the scheduled machine to establish machine capabilities and to get the best setup possible. Tests are made on coupons with a portable hydraulic tensile tester of 40,000 lb. capacity. Both shear and tensile tests are made, and control settings of machines are recorded. The weld is closely examined for porosity, size, tip indentation and general appearance in addition to strength requirements.

When the procedure gives satisfactory results, triplicate sets of cards are made. One is given to the Time-study Department, noting that the job is ready to time and should be timed, as shown on card, for machine setup and strength of welds. After the time study is made, one card is placed with the machine. The third is retained by the Welding Engineer. This system, when fully completed, permits every operator to make setups in a minimum of time and warrants best setups for quality. It simplifies the foreman's job and permits quicker substitution of employees during vacations, absences, etc.

Jobs that are not adaptable for testing on the portable unit are taken to our laboratory for complete analysis and testing.

One interesting flash-weld job is on the main-frame side channel noted in Fig. 3. Here a 5-in. channel is

Fig. 3 Main frame side channel—showing a 5-in. channel flash welded to a forging

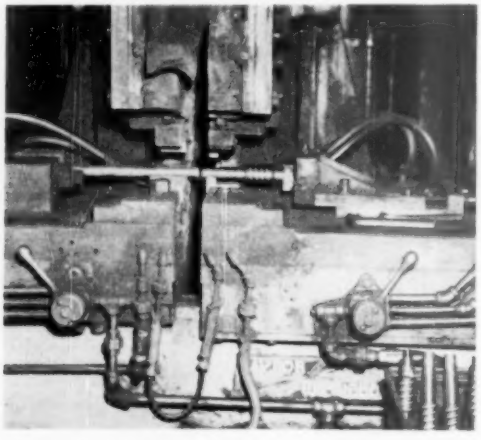

Fig. 4 Set-up of shaft and worm gear in a flash welder. After joining it will become the steering worm shaft

welded to a steel forging in a 600 kva. hydraulic-operated flash welder with tempering attachment. This type of weld is cross sectioned and etched to determine fusion and grain flow. Strips 1 in. wide are sawed out for tensile tests. Machine settings are then developed to result in a sound weld joint, stronger than the perforated channel. Welding on this channel is a two-man job with one man trimming the hot flash off the weld with an air chisel while the other manipulates the machine. Production on this is over 50 channels an hour, using one semiautomatic machine.

Another good flash-weld operation is the steering worm shaft shown in Fig. 4. The worm is made of heat-treated 8620 steel and the $^{7}/_{8}$-in. diameter shaft of C-1025. Shown in the picture are two parts loaded in the machine prior to clamping and lowering of safety shield. The weld is made on a 200-kva. machine. The flash is then immediately hot-turned in an adjacent lathe. This is done by using a plunge-cut with a Stellite cutter which turns the shaft to a uniform diameter. Normally, the weld is not visible to the naked eye. After turning off the flash, the assembly is placed in vee-type checking fixture (Fig. 5) and a dial indicator used to check alignment. This is a very critical weld joint and represents another of the many varied jobs required in tractor manufacture.

Constant research and experiments are being made in welding to find better ways to not only do the welding but to make better finished products at lower costs. The essence of free enterprise is characterized by competition, and this competition makes it necessary and a pleasure to find better ways of doing the job. Examples of just a few cases will be given in which we have

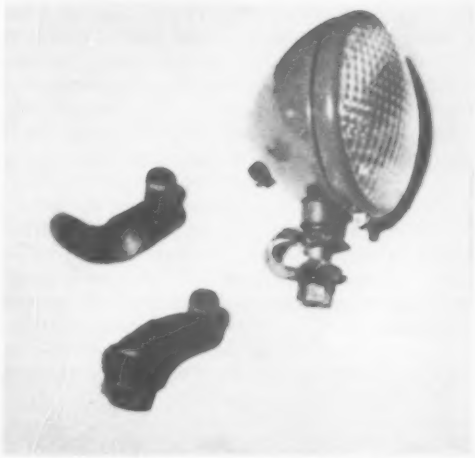

Fig. 6 Steel and malleable iron taillight bracket showing new projection weld design at top. Lamp clamps on round pin

reanalyzed welding procedures or redesigned parts for welding at lower costs.

One way used to approach these economies has been by the careful examination of projection-welding dies to determine the parts most frequently reworked. Improvements are made to give better cooling, improved die life, locating devices, etc. All parts are studied, along with the production made, to ascertain what degree of improvement has been made. We have actually increased the life of some dies by 400% between regrinds because of the above analysis. This

Fig. 5 Hot turning flash from welded steering worm shaft. Checking fixture appears in foreground

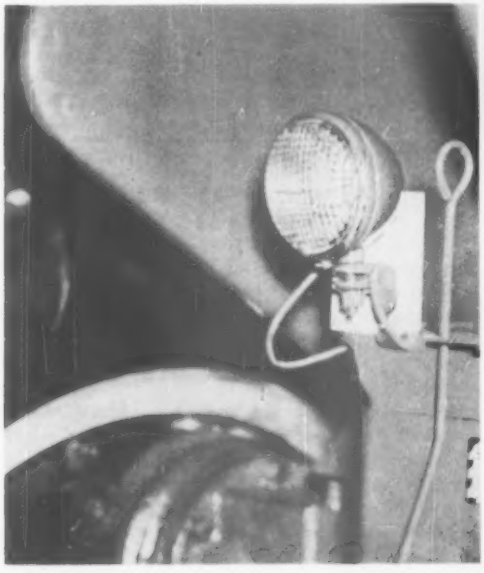

Fig. 7 Location and appearance of new design taillight bracket on tractor. (White card used to show details)

means better welds with fewer setups and, of course, lower costs. Sometimes, a reanalysis of a welding die leads one to make changes in the routing on fabricated parts that may permit easier loading and unloading during a welding operation. It is our policy to continually recheck the tooling and welding processes for improvements regardless of how they appear when originally set up.

The physical size of an assembly does not indicate the amount of savings or improvements that can be made. A case history of a taillight bracket will be used to illustrate (Fig. 6). This bracket was originally made of malleable iron and had been our accepted standard until it was reanalyzed. Figure 6 shows a steel-welded assembly on the left and a malleable iron part on the right. The lamp is pictured nearby to show assembly. This welded design showed a savings

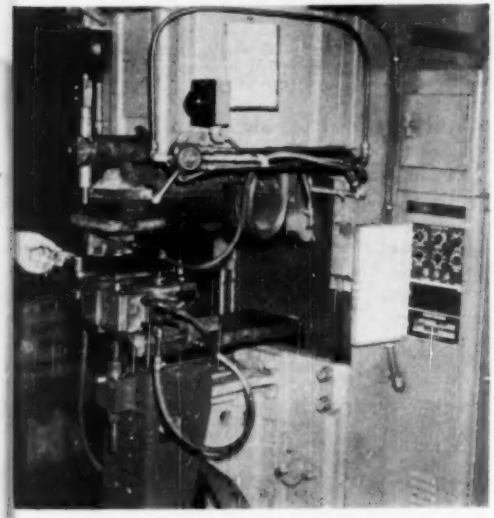

Fig. 8 Projection welder with N-3-H controls used to weld taillight bracket shown in operator's hand

of 61.4% of the former cost, plus making a better product.

Figure 7 shows the taillight and bracket attached to the tractor, presenting a neat appearance.

Figure 8 shows the welding arrangement on a 250-kva. machine with full electronic controls, air vise and knee support for rigidity. The vise and platens were originally designed for this specific assembly but are so versatile they may be used on others.

Figure 9 shows how air vise is mounted on tee-slotted platens. The throat of the machine is open for large work, and, when two dies are required, the vise can easily be removed without disturbing the cylinder on the side of the machine.

The taillight bracket is made from two pieces of mild C. R. steel—a $^3/_8$-in. diameter pin and a $^7/_{32}$-in. flat strip. Cost of the bracket, using two designs, is given below:

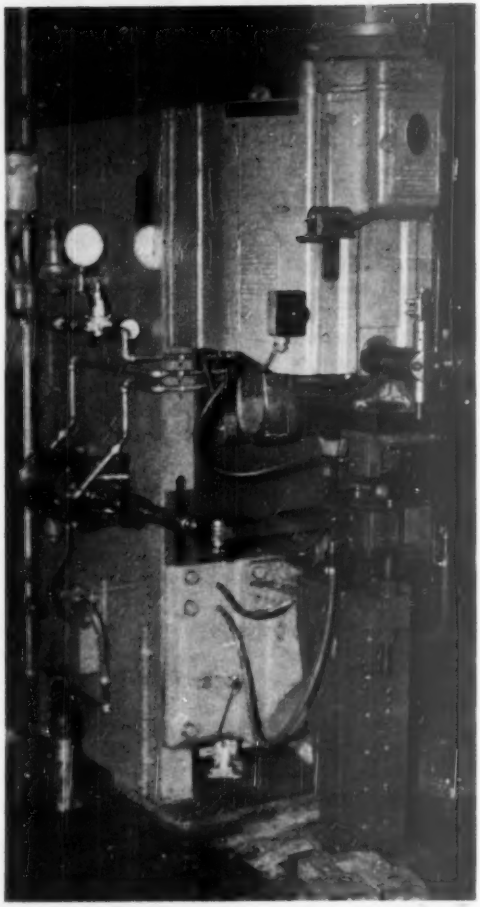

Fig. 9 Vise and die arrangement used when welding taillight bracket. Vise is removable for welding other jobs, and can accommodate shafts 30 in. long

Former: $18.30/C for material and labor

New welded design shown in Fig. 6: $5.21 /C for material and labor

In addition, the new design required the use of a shorter bolt, making another savings of $1.03/C. Former manufacturing cost was $22.99/C. New design cost $8.87/C, leaving a total savings of $14.12/C or a savings of 61.4% on basic product cost. Also, the new design,

Fig. 10 Shifter levers with former arc weld design shown on left. New projection welded part on right

with the $^3/_4$-in. round pin, gives a uniform area for the gripping clamp of the lamp instead of the tapered natural draft on casting, thus resulting in a better product.

Another development arrived at through research was changing the power take-off lever from arc welding to projection welding. The original design was difficult to arc weld properly on a production basis and required cleaning off excess flux. The new design lowered product cost and resulted in a better product. An illustration is shown in Fig. 10. Note that the plate design was changed to permit better use of steel at a savings of $.18 per hundred. Four projections were made in the plate during blanking operations, thus preparing it for resistance welding. The projection weld operation costs less than the arc-weld process on this assembly. Relationship of basic-product cost shows a reduction from $3.52/C to $1.67/C or a reduction of 52.5%.

Machine operations, after welding, include drilling a $^9/_{16}$-in. hole through center of block, leaving the four welds intact at each corner. Physical tests indicate steel plate to pull in two, leaving the four welds intact, one at each corner of the block. This improved welding job represents another example of continued research and development in the manufacture of tractors.

The streamlined fuel tank shown in Fig. 1 is seam welded with precision electronic controls. The tank is made of terne-plate and has projection, spot, braze and solder operations in addition to the 82-in. seam weld.

Production arc welding and brazing are done in well ventilated booths that are equipped with cast-iron insulated table tops, overhead fluorescent lighting, nonreflecting wall paint and other design features that provide many advantages for the operator. Double booths are set up in "rooms" with each "room" accommodating two people. The welding machine is placed at one end of the booth on a framework housing all fixtures required in that "room." Swinging doors on the all-metal booths permit trucks to bring in stock and to remove heavy tote boxes of assemblies. Each "room" contains shelves and storage bins for storing all normally required materials. This permits operator to do full production welding with a minimum of stocking up and preparation time and adds up to a better flow of production material. All booths are regularly checked for proper ventilation and safety and have been highly commended by shop visitors acquainted with production welding.

Another model tractor is shown in Fig. 11, termed the wide-front axle type. This front tubular steel axle, with supports, guide bushings, rods and wheel hubs, involves over a dozen arc welds and two flash welds. Such method of construction gives a strong product at a minimum cost.

Fig. 11 Wide front axle type tractor illustrating places where arc and flash welding are used extensively

Fig. 12 Bronze weld made on a broken punch press frame. Seventy-five pounds of bronze was used on this repair

Other forms of joining used in tractor manufacture involve furnace brazing and induction brazing of numerous parts. One small item that was formerly arc welded was redesigned for furnace copper brazing with an annual saving of more than $40,000. Such items as radiators have some parts soldered with induction heating. Other parts require silver or copper-alloy rings for induction brazing.

In addition to welding production items used on the tractor, we also must keep all production machines operating. Welding maintenance covers an extended field and is far too complicated to attempt a description here. Suffice to say, we make all our own repairs in welding, ranging from minor arc-weld or brazing operations to large machine repairs.

Figure 12 shows a 100-ton punch press that failed through the bed and frame. This casting was bronze welded with low-fuming, flux-coated rod. This press has been operating daily for two years since repairing and is still satisfactory.

We recently welded and installed a high nichrome

muffle for a carburizing furnace. This involved delicate welding on a casting that cost $10,000. These examples are given to illustrate the range of welding done in machine maintenance.

Two items of salvage will be reviewed which include salvage of grey-iron production castings and tool-room work. Castings are repaired by many processes after tests and procedures have been worked out to do the job. Written procedures are drawn up by the Welding Engineer and are rechecked and signed by the Plant Metallurgist and Chief Inspector. Four copies are made up for the particular repair with one copy going to the Salvage Department as their authority and to give the procedure for the respective repair. It is found that this system works out very satisfactorily.

In salvaging tools, we also make tests and then establish procedures so that similar applications may be used repeatedly without further tests or investigation. We salvage broken broaches by fixturing for alignment and brazing together. Broken teeth in broaches and milling cutters are built up and reground to size. New tangs are brazed on broken drills, and tools are then returned to production. Multiple carbide milling cutters are repaired with new inserts and reground.

Our salvage of all types of tools is extensive, and the results are very satisfactory. Salvaging enables us to get more use out of a tool before discarding it. Investment in new tools is lower, and production is kept supplied at all times with a minimum of "emergencies" in the tool room.

Harvester maintains a research department for aiding local plants on problems that such plants are unable to handle. Long-range research projects and technical assistance are provided by this research laboratory.

International Harvester Company finds that welding not only makes money, but saves money, and the manufacture of tractors is dependent upon the many processes of welding used. Its use is increasing, and, by continued research, we will be able to benefit still further from the many advantages of welding.

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Pipe, Steel, Manufacture. Electric Weld Tube Mill Goes Into

(*Continued on page 1004*)

Cast Iron Repair

This large cast-iron mill was repaired by fusion welding with cast-iron rod. It would have been easier to repair it by bronze welding, but in service the mill holds cyanide solutions that would attack a bronze weld

By A. J. Beldon

THIS piece of mining equipment had been in service for 16 years when it developed a crack through the 2-in. thick flange near the base of the trunnion. The diameter of the trunnion was 18 in. and the crack was 40 in. long. As Fig. 1 shows, the crack was veed out by chipping, then a preheating furnace was built by forming a firebrick wall around the flange. Charcoal was used for the fuel. The complete unit was held off the ground by steel rails.

Temperature-indicating crayons were used to show when the proper preheat temperature of about 500 to 600° F. had been reached. Then two welding operators started welding as shown in Fig. 2. They used cast-iron welding rod $^1/_2$ in. thick as filler metal. Airlines were arranged to direct blasts of air over the welding zone to reduce the effect of the heat on the operator and also to remove fumes. The job took 5 hrs. welding time. As soon as the welding was finished the unit was covered with asbestos paper and allowed to cool.

A. J. Beldon is connected with The Linde Air Products Co., Birmingham, Ala.

Fig. 2 A preheating furnace was built from firebrick and the casting was preheated with charcoal to about 500 to 600° F.

A new part would have cost $150 more than the repair job. However, new parts could not be delivered for from 4 to 6 months and the loss of production would have cost about $500 per day.

In all cast-iron welding its important to preheat the part well and to allow it to cool slowly. Quick cooling will make the weld hard and unmachinable.

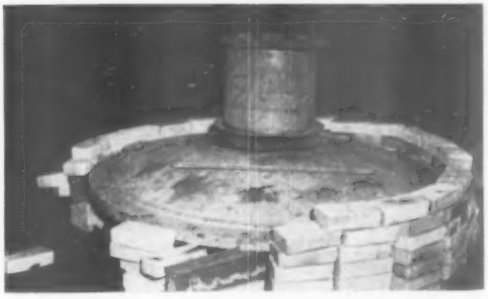


Fig. 1 The 40-in. crack in this cast-iron part was prepared for welding by chipping

Fig. 3 When the welding was completed, the unit was covered with asbestos paper and allowed to cool

WEAR YOUR AWS EMBLEM

Welded Rail Costs Trimmed

A HOT trimming device, used for the first time on the Illinois Central continuous welded-rail program in South Chicago, has reduced the grinding operations to one-fifth of the usual amount needed, with important savings in grinding wheels and man-hours.

After pressure welding, the excess metal formed at the weld must be trimmed from the top and sides of the rail ball. In the past, this was done with an oxyacetylene blowpipe. As it is difficult to trim this upset close to the rail surface, an excessive amount of grinding was needed on the area. With the new hydraulic trimming device, tools tipped with "Haynes Stellite" hard-facing alloy plane the top and sides of the ball to a close tolerance, thus reducing the grinding operation.

The weld area is trimmed at a temperature of about 2000°F. If the trimming is done immediately following welding, no reheating is required. If the temperature has dropped, the area to be trimmed is quickly reheated with an oxyacetylene blowpipe. The hard-faced blades make the cuts while the metal is being reheated.

Fig. 1 Here is how the excess metal is trimmed

The trimming machine saves many man-hours and makes important savings in grinding wheels

The hot trimming machine was developed by The Oxweld Railroad Service Co., Unit of Union Carbide and Carbon Corp.

Welding in the Oil Fields

RIGGING up operations of a steam rig near Long Beach, Calif., employ welding in numerous ways. Here a flange is being welded to piping (Fig. 1). Efficient welding trucks move 300-amp. gas engine driven welders about the area (Fig. 2). Hard-facing drill pipe was the operation on the other end of the cables when this picture was made. Some novel features of the truck include welding cable storage bin on either side at the rear of the vehicle. Hinged lids, shown open here, keep out rain and weather, thus affording protection to the rubber lines. Raised wells above the rear wheels afford a flat working table in addition to other working space. The walkway steel plate attached to the sides and rear of the body gives the truck a low streamlined appearance and serves as a useful guard from bumps and knocks encountered in field work. Reflectors placed at each corner of the body and the two at the rear give added protection during night highway travel. A trailer hitch, seen below the licence plates, comes in handy when additional equipment is needed on the job.

Data and photos, Courtesy The Lincoln Electric Co., Cleveland, Ohio.

Figure 1

Figure 2

Weatherproof storage for welding rods, conveniently located, keeps different size rods and other welding equipment in easy reach of the busy welder (Fig. 3). The box is constructed of lightweight steel, and divided into compartments for separating different size rods from other accessories. The hinged top makes the receptacle weatherproof. Mounting the unit beneath the truck floor makes for easy access, and gives cleaner lines to the vehicle.

Efficient storage bins prolongs life of welding cable (Fig. 4). These weatherproof bins are located at the rear of the welding truck, and are fabricated from discarded oil well casing. The tops, or covers, are made from lightweight sheet steel and are hinged to the truck floor. The cables are neatly stored when not in use, and when needed, the lines play out rapidly without kinks.

Figure 3

Figure 4

Figure 5

Efficient trap farm walk-way made from scrap materials (Fig. 5)—A safe and attractive stair for personnel on a trap farm can be readily welded from scrap materials. The frame of the stairway is constructed of angle iron with stairs and landing being covered with expanded metal. Discarded sucker rods are used for the guard rail.

Diesel Manifolds Economically Repaired

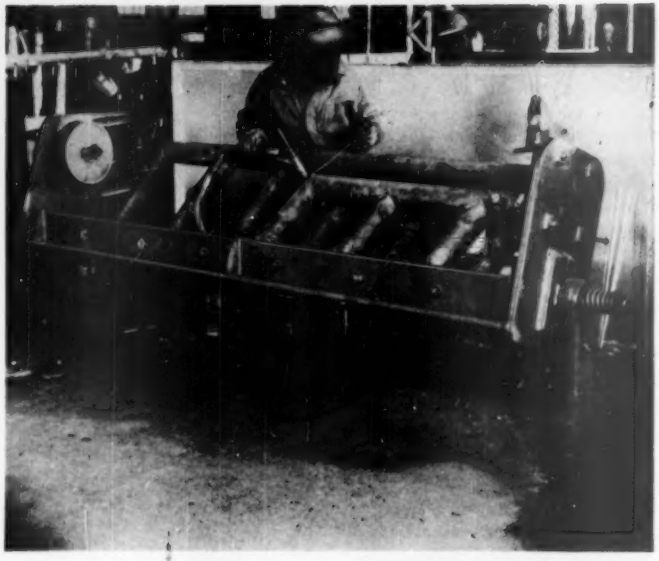
CRACKS in stainless-steel exhaust manifolds for Diesel locomotives are economically repaired by means of inert-gas-shielded arc welding at the shops of the Lehigh Valley Railroad. The cracks develop where the manifolds were previously joined and permit exhaust gases to escape. These gas leaks are troublesome and dangerous and the manifolds must be replaced or repaired.

The railroad uses a special jig-positioner as shown in Fig. 1, to hold the manifold during the repairs. First, all of the lagging is removed from the manifold which is then taken apart for realignment in the jig. The parts are placed in the jig so that the operator can reach easily all of the areas to be welded.

Once the manifold is set up in the jig, the operator goes over all cracked places with a Heliarc torch and adds filler rod. Local heating of the arc shows up small cracks which are also filled with the Oxweld No. 28 columbium-bearing stainless-steel filler rod. The weld repairs cracks and also relieves the stresses caused by the original joining.

After making each weld, stresses are further relieved by heating the pipe for about 3 in. on each side of the weld. The pipe is heated to about 1600°F. with an oxyacetylene blowpipe flame. This stress-relieving operation also helps prevent buckling and distortion in the assembly.

After completion of the welded repairs, the holding bands are reapplied and a shipping strip is welded to the flanges. Next step is to apply a 1-in. thick layer of new lagging. The manifold assembly and the jig is removed as a unit, placed on wheels, and wheeled into a furnace to bake the lagging. Cost of reconditioning, is said to be about $40 for a complete manifold of this type. This does not include the application of the new lagging.



Courtesy Orweld Railroad Service Co.

Fig. 1. Jig-positioner used to hold manifold during repairs

The manifold shown has 48 locations that are reworked or repaired in this way. Argon gas is the shielding medium. The current is a. c. with imposed high frequency.

(*Continued from page 1000*)

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the AMERICAN WELDING SOCIETY

activities • related events

R.W.M.A. Prize Contest Winners Announced

Winners of the R.W.M.A. 1950 Prize Contest have been announced by the Jury of Award. They are as follows:

Category No. 1—Papers emanating from an Industrial source:

First prize of $750 awarded to the paper entitled "A Practical Method for Obtaining Consistent Resistance Welds," by J. W. Kehoe, Westinghouse Electric Corp., Pittsburgh, Pa.

Second prize of $500 awarded to the paper entitled "Stress Distribution Around Spot Welds," by A. O. Bergholm, P. W. Swartz and G. S. Hoell, The Franklin Institute, Philadelphia, Pa.

Third prize of $250 awarded to the paper entitled "Variables in Cross-Wire Welding of Dissimilar Metals," by I. S. Goodman, Westinghouse Lamp Division, Bloomfield, N. J.

Category No. 2—Papers emanating from a University source, the author of which is either an Instructor, Graduate Student or Research Fellow:

First prize of $300 awarded to the paper entitled "Fatigue Tests of Spot-Welded Steel Sheets," by Dr. Georges Welter, École Polytechnique, Montreal, Canada. (This paper was published in the September 1949 WELDING JOURNAL.)

Second prize of $200 awarded to the paper entitled "Electrical Resistance Offered to Nonuniform Current Flow," by W. B. Kouwenhoven and W. T. Sackett, Jr., Johns Hopkins University, Baltimore, Md. (This paper was published in the October 1949 WELDING JOURNAL.)

Category No. 3—Papers emanating from a University source the author of which is an undergraduate student:

There was only one paper submitted under this heading and in the opinion of the Jury this paper did not qualify under the definition set up by R.W.M.A.

Biographies of some of the prize winners are published elsewhere in the JOURNAL.

A. E. Gaynor Memorial Resolution

The following resolution prepared by J. B. Tinnon, *Chairman*, Chas. Kandel and George Schneider was approved by the Board at its meeting on August 29th.

"The Directors of the AMERICAN WELDING SOCIETY record with profound sorrow the death of A. E. Gaynor after a lifetime of devoted service to the Society and the welding industry as a whole.

"Mr. Gaynor was one of the founders of the New York Section of the SOCIETY and from its inception in 1920 through 1930 served on the Executive Committee of the New York Section. He was a member of the Board of Directors of the National Society from 1926 through 1940 and served three terms as Senior Vice-President.

"During his active years as a member and officer of both the National Society and the New York Section, Mr. Gaynor gave unstintingly of his time and energies to the development of the SOCIETY. His great ability, his analytical mind and his helpfulness contributed greatly to the early successes of the SOCIETY. His congenial spirit and sterling example of loyalty, earnestness and integrity endeared him greatly to his many friends and associates.

"It is hereby resolved that this summary of Mr. Gaynor's connection with the SOCIETY be recorded in the minutes of the Board and a copy sent to his family with the deep sympathy of the Society."

Sustaining Member

National Certified Pipe Welding Bureau, Suite 1401, 1250 Avenue of the Americas, New York 20, N. Y. A department of the Heating, Piping and Air Conditioning Contractors National Association, consisting of piping contractors in the power and industrial field, organized to engage in research and educational work in pipe welding, to disseminate information concerning methods of welding pipe, to establish and qualify standard procedure specifications for pipe welding, to provide for the interchange of records of qualified pipefitter welders, and to promote and develop the use and to maintain the quality of welding in the pipefitting industry.

Board of Directors Meeting

A meeting of the Board of Directors of the AMERICAN WELDING SOCIETY was held in Hotel Statler, New York, Headquarters Room at 10:00 A.M. on Tuesday, Aug. 29, 1950, with the following in attendance:

Members: O. B. J. Fraser, *Chairman*, L. C. Bibber, A. F. Davis, R. S. Donald, H. O. Hill, T. M. Jackson, C. I. MacGuffie, H. W. Pierce, L. C. Stiles, H. S. Swan and J. B. Tinnon.

By Invitation: H. Biers, D. Joseph, A. G. Oehler, W. Spraragen and J. Lyell Wilson.

A.W.S. Staff: J. G. Magrath and F. J. Mooney.

Acceptance and Approval of Finance Committee's Proposed Budget for Society Operation During the 1950–51 Fiscal Year.

D. Joseph, A.W.S. Auditor, pointed out that for the 11-month period ended July 31, 1950, the SOCIETY suffered a net loss of $14,218.21. This loss was caused primarily by failure to realize income budgeted for the sale of *Welding Handbook and Welding Metallurgy.*

He stated that the proposed budget of income and expense for the 1950–51 fiscal year is very realistic. The important items to be considered are income to be derived from the sales of the *Welding Handbook* as well as income to be received from membership dues and JOURNAL advertising. The budgeted income to be derived from membership dues is an actual billing amount which should be acquired.

Relevant discussion at length followed covering various activities of the SOCIETY including presentation by Lyell Wilson, Vice-Chairman of the T.A.C., and Chairman of T.A.C. Subcommittee on Budget, of proposed expansion of T.A.C. activities to accommodate industries' requirements. Mr. Wilson's presentation was essentially the same as that given to the Finance Committee (refer to minutes of Finance Committee meeting). Following the discussion, the proposed budget as submitted by the Finance Committee was approved subject to quarterly review for the purpose (1) considering salaries suggestions and employing additional personnel in the T.A.C., if circumstances permit and (2) the SOCIETY actively investigate and attempt to raise funds specifically for technical activities.

Mr. Wilson emphasized that it was impossible for the T.A.C. to either do the things as planned for or to show results expected of it without strengthening its organization by the added personnel requested in its presentation to the Finance Committee. As before stated it was agreed by the Board that (*a*) all were in favor of the T.A.C. recommendations (*b*) that at this time the budget did not allow fulfillment of same and that (*c*) ways and means will be sought at once toward providing the necessary funds to enlarge the scope of T.A.C. activities.

A.W.S. Student Chapter at Utah State Agricultural College

Utah State Agricultural College, located at Logan, Utah, having fulfilled all the qualifications necessary for the establishment of a Student Chapter at their College requested that formal authority to operate as the Utah State Agricultural College Student Chapter of the A.W.S. be granted them.

Upon motion, duly seconded, the Board of Directors so approved.

Discharge of Welding Handbook Committee with Vote of Appreciation

The Welding Handbook Committee, having completed its task in the publication of the new third edition of the *Welding Handbook*, was discharged by the Board of Directors with a vote of sincere appreciation and commendation for its unique and most valuable services. The Secretary was directed to prepare and send a letter of appreciation to the members of the Welding Handbook Committee who gave unstintingly of their time and services.

The Welding Handbook Committee's recommendations regarding the mechanics for producing a fourth (next) edition of the *Welding Handbook* were tabled until such time as it may be necessary to consider the formation of an organization for the purpose of producing a next edition of the *Welding Handbook*.

Canadian Welding Bureau Course

The Secretary stated that R. M. Gooderham, General Manager of the Canadian Welding Bureau, submitted a proposed contract to A.W.S. for the purpose of selling a correspondence welding course here in the United States. The proposed contract was submitted to the SOCIETY's attorney for review and comment thereon. The SOCIETY's attorney has requested that he be given ample time to completely study the contract before reporting on its legality.

President Fraser read letters at this meeting from Messrs. Sieger, Jennings and Jefferson in which all three gentlemen raised objections to the institution of such a course in this form.

Mr. Pierce stated that this course is not for the purpose of teaching a man how to weld. Rather it is a welding engineering course which will benefit welding supervisors and those aspiring to supervisional positions as well as further the education in welding engineering of engineering design, drafting and supervisory personnel.

Mr. Joseph, A.W.S. Auditor, suggested that before the SOCIETY decide definitely to adopt the Canadian Welding Bureau course as proposed by Mr. Gooderham, that it look into the possibility of other means for producing a correspondence course supplemented by slide films for study groups and supporting lecture courses. He had in mind a specific organization which has successfully conducted such activities.

It was observed by Mr. Fraser that if we considered Mr. Gooderham's recommendation for adopting the Canadian Welding Bureau's course that the course would have to be supplemented with chapters treating with gas welding and the allied processes. Mr. Bibber suggested that it might be better of A.W.S. set up its own correspondence course in view of the fact that much of the Canadian Welding Bureau's correspondence course was built around American standards produced by the AMERICAN WELDING SOCIETY. After considerable discussion the Board of Directors upon motion, duly seconded, voted that (1) the SOCIETY's Secretary be authorized to negotiate a contract with Mr. Gooderham, subject to the advice of the SOCIETY's attorney and (2) that technically-wise the course meet with the approval of the SOCIETY's Technical Secretary and Chairman of the National Education Committee and (3) that the arrangements be totally satisfactory to the Officers of the SOCIETY before consummation of contract.

Recommendations of the Technical Activities Committee

The T.A.C. recommended to the Board of Directors that invitation to appoint an A.W.S. representative to A.S.A. Sectional Committee C63, Radio-Electrical Coordination, be accepted and that A. N. Kugler, Air Reduction Sales Co., be appointed official A.W.S. representative.

Upon motion, duly seconded, the Board of Directors so approved.

A. E. Gaynor Memorial Resolution

At a meeting of the Executive Committee of the SOCIETY on June 7, 1950, a three-man committee consisting of J. B. Tinnon, *Chairman;* C. Kandell and G. Schneider were appointed to prepare appropriate memorial resolution to be spread on the records of the SOCIETY and transmitted to Mr. Gayner's family.

At this meeting, appropriate memorial resolution for the late Mr. Gaynor, as prepared by this Special Committee, was confirmed and by vote of the Board of Directors the resolution was adopted for the records of the SOCIETY and transmittal to Mr. Gaynor's family.

(Continued on page 1010)

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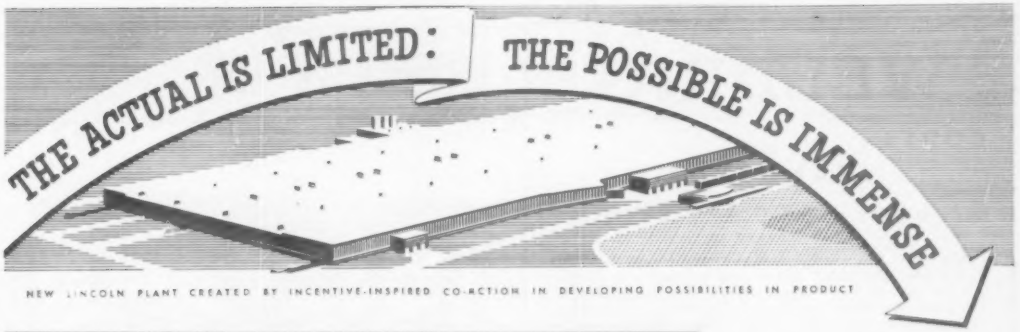

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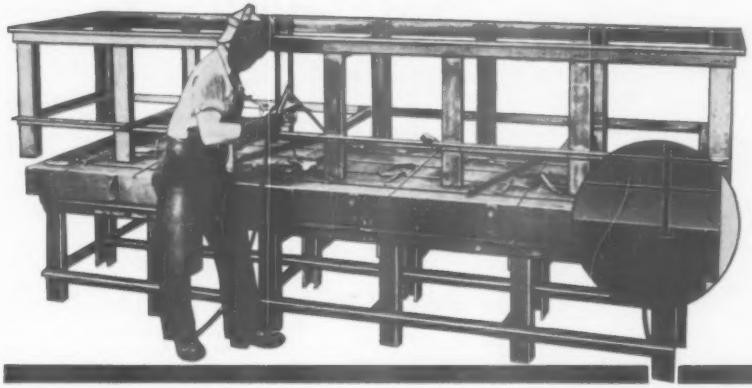

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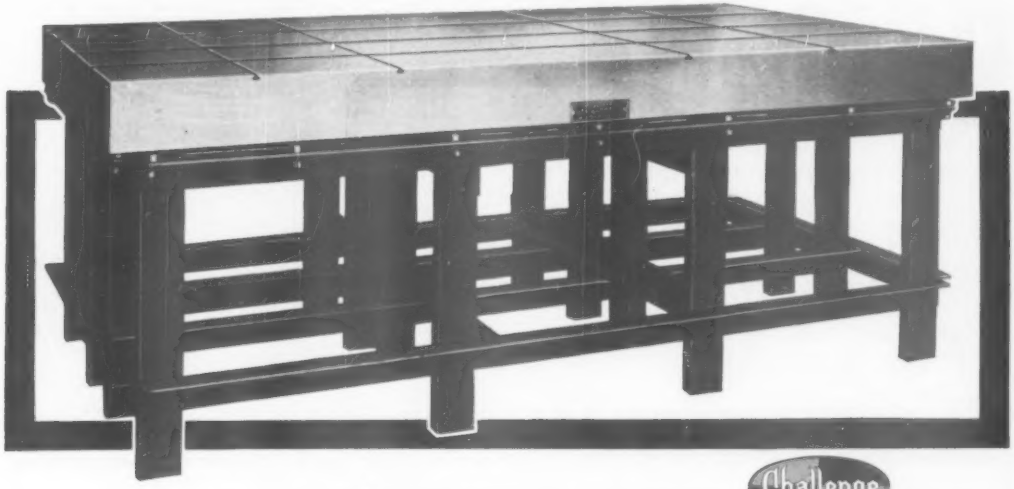

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Approval of Jerome Welch to Serve on R.W.M.A. Jury of Award

The Board of Directors approved the appointment of Jerome Welch, Cutler-Hammer, Inc., Milwaukee, Wis., to serve on the R.W.M.A. Jury of Award to fill the unexpired term of one of its members who tendered his resignation. The unexpired term is for the years 1950 to 1954.

A.W.S. Membership in I.I.W. for Calendar Year 1951

Howard Biers, member-at-large of the A.W.S. Committee on I.I.W., reported that he attended the recent meeting of the International Institute of Welding which was held in Paris, France, June 5–10, 1950.

He observed that this was the second full-scale meeting of the I.I.W. and that 350 members attended, representing many European countries. The reports rendered at the meeting are not as yet available in printed form.

The work of the I.I.W. is still organizational, its purpose being to raise the level of welding in technical Europe, to that already prevailing here in this country.

Mr. Biers stated that the I.I.W. operates on a yearly budget of £750, of which the United States and England each contribute £175. U. S. withdrawal would be a severe financial blow to the I.I.W. project. Next year's meeting should prove highly successful and it is anticipated the attendance will be 500 or more. Accordingly, he recommended to the Board of Directors that A.W.S. should continue membership in the I.I.W. for the calendar year 1951 for reasons that (1) to protect our self interests as it is highly undesirable for any other country to replace the U. S. as the leading exponent of welding and the allied processes (2) membership in the I.I.W. is very helpful in maintaining the already acquired position of the A.W.S. standards.

Upon motion, duly seconded, the Board of Directors voted favorably to continue A.W.S. membership in the I.I.W. for the calendar year 1951.

The Society's Secretary was of the opinion that the I.I.W. activity should be a function of the Technical Activities Committee. The Board of Directors, upon proper motion, voted to refer this matter to the A.W.S. Committee on I.I.W. for consideration and recommendations thereon and that the Society's Secretary be empowered to follow through with recommendations of the A.W.S. Committee on I.I.W.

Welding Journal Questionnaire

A. G. Oehler, *Chairman*, Welding Journal Committee, reported that on Jan. 23, 1950, with the approval of the Board of Directors, a questionnaire was sent to the entire membership to ascertain reader interest in various sections of The Welding Journal.

On April 1, 1950 the returns were declared officially closed and the task of analyzing the 726 replies was undertaken. Each questionnaire had 115 possible votes and 11 places for comments. These votes were further divided in 16 job categories.

The comments occupied 155 typewritten pages and the votes reduced to percentage basis occupied 10 additional pages.

Briefly the results of this questionnaire led to the following basic conclusions:

1. The Journal as a whole is helpful to 95% of the responding members. Three per cent of our responding members had difficulty in locating the Contents page and therefore the Welding Journal Committee recommends that the cover be redesigned to include the feature articles and the page location of the Contents page and Advertisers Index.

2. The Engineering and Technical Articles are acceptable to 88% of the responding members and should not be changed.

3. The Practical Welder and Designer Section is liked by 78% of our responding members and should be continued in about the same proportion.

4. The Principal Departments in the News Sections are well received. Examples:

	%
Society and Related Activities	71
News of the Industry	88
New Literature	85
New Products	99
Section Activities	60

5. The Research Supplement should be continued. Fifty per cent voted against separation and only 22% voted in favor of separation.

6. The Advertising is read by 88% of our responding members and found helpful

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Specialists in Stainless, Low Alloy and Non-Ferrous Electrodes

by 74% of them with 49% making actual purchases as a result of ads in the JOURNAL. These comments will form the basis of a new advertising brochure.

It developed that a number of people felt improvements could be made to the front cover of the JOURNAL and another group believed that the contents should be shown on the front cover. The total of these two groups was sufficient to warrant the Committee's consideration of their recommendations and a redesign of the front cover, to include the major article content. It was observed by Mr. Oehler that this change will effect a slight saving in production costs. The Secretary observed that he had made an independent check of the returns by the responding readers on the basis of an occupational survey, a method different from that employed by THE WELDING JOURNAL Committee in its analysis. The Secretary reported that based upon his exploration, THE WELDING JOURNAL Committee's report was a true representation of the responding readers opinion. He observed that while it was not certain that all JOURNAL readers were of the same opinion as the responding readers, a survey of this type and a similar representative percentage of return, were accepted as authoritative by many publishers and survey makers. The Secretary felt that therefore we could accept the opinions of the responding readers as reasonably indicating the feeling of the SOCIETY's membership. If a further analysis of the questionnaire is desired, then a committee of three should be appointed to carry out this assignment.

He observed that it was very important either to find out the opinions of those who neither are in the SOCIETY nor read the JOURNAL in order to learn the proper pattern for interesting such people in SOCIETY membership.

Detailed Analysis of Journal Questionnaire

The Secretary reported that the 10-page detailed analysis of replies received covering the JOURNAL Questionnaire, as submitted by the WELDING JOURNAL Committee, was very well summed up.

J. B. Tinnon observed that the SOCIETY's advertising revenue and membership registration is not as expected because the present mebership is not satisfied with the JOURNAL as it is now published. He voiced disapproval of publishing Annual Meeting papers as late as eight or nine months following the presentation of such papers at the SOCIETY's Annual Meeting. Mr. Oehler agreed in large part with Mr. Tinnon's ideas but stated that THE WELDING JOURNAL Committee does not have the budget to do all the things Mr. Tinnon may have in mind.

The Secretary pointed out that based on last year's Annual Meeting registration, in which 54% of those registered were not members of the SOCIETY, the membership potential for the Society is 15,000.

He stated that he has found that both THE WELDING JOURNAL Committee and the JOURNAL Editor, as well as others, are favorable to the production of a publication which will not depend upon Annual Meeting papers for its text. In order to obtain the popular type of articles written

WELDING MONEL?

Which electrode do you need...

"140"?
"130X"?

Both the "140" and "130X" electrodes are used for welding Monel®, but each of these rods is designed to do a specific job.

For best results... sound, strong, corrosion-resistant welds... it pays to make sure you have the right rod for the job at hand.

Check the following table carefully when in doubt ...and file it for future reference!

QUESTION	• "140" ELECTRODE	• "130X" ELECTRODE
1 Which rod is right for welding solid Monel in all positions?	May be used if no "130X" is at hand.	Best
2 Which rod for overlaying Monel directly on steel?	Yes	No. A barrier layer of nickel must first be laid down.
3 Which for joining wrought or cast Monel to steel or stainless steel?	Yes	No
4 Making direct Monel-to-steel welds?	Yes	No
5 Joining Monel to nickel?	Yes	Best
6 What are the recommended amperages?	3/32" 35-60 amp. 1/8 " 70-110 amp. 5/32" 110-150 amp. 3/16" 140-190 amp.	.075 " 25-40 amp. 3/32" 45-60 amp. 1/8 " 60-95 amp. 5/32" 80-150 amp. 3/16" 140-190 amp. 1/4 " 170-260 amp.
7 What type of current and polarity must be used?	D.C. Reversed polarity.	D.C. Reversed polarity.
8 Are the corrosion-resisting properties of the weld deposit comparable to those of the parent metal?	Yes	Yes
9 Do the mechanical properties of the weld deposit compare with those of the parent metal?	Yes, assuming parent metal is in the soft-temper condition.	Yes, assuming parent metal is in the soft-temper condition.

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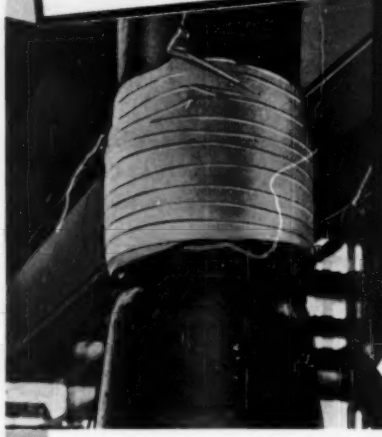

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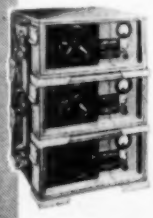
Welded Joint in 20" O.D. — 1⅜" Wall Carbon Moly Boiler Down-Comer Partially Wrapped for Stress Relieving.

- **Smith-Dolan Heating Apparatus can be easily and safely handled by regular job personnel.**
- **It will deliver consistently perfect results under safe conditions assuring minimum job costs.**
- **Thorough heating of heavy wall metal sections can be achieved in a minimum of time with precise control.**
- **Proper heating is delivered according to set specifications and requirements of the Boiler and Piping codes.**



***NEW MODEL U-P** — Patented Smith-Dolan System, portable, low frequency induction heater, three-high stack (shown) 30 kva, 10 kva per unit. Buy one or stack two or three for increased capacity. Buy what you need; build as you go.*

***AUTOMATIC CONTROL CABINET** used with Model U-P units (shown) and Model GC Duplex 120 or 150 kva induction heaters (shown in catalog).*

Electric Arc equipment can be rented or purchased for any job requiring preheating and stress relieving for welding and normalizing.

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in an industry promotion style, it would be necessary to supplement THE WELDING JOURNAL staff with an additional field editor who could secure such stories in the field and possibly then publish the various papers given at the Annual Meeting in the order of "Transactions" issued either quarterly or semiannually. However, in order to do such it would be necessary for the SOCIETY to find additional funds to the extent of $50,000. Such, at the present time, is not forthcoming in advertising or other sources of revenue and therefore the SOCIETY is forced to hold to the present pattern which, admittedly, may not be the best pattern. As organized, we are producing a publication within our means. Greater improvement in our organization and publication production can be accomplished if additional funds can be found.

After receiving the foregoing comments, the Board of Directors, upon motion, duly seconded, extended a vote of thanks to THE WELDING JOURNAL Committee for its most comprehensive and illuminating report.

Renewal of Agreement of W.R.C. Supplement

The Board of Directors upon motion, duly seconded, renewed with W.R.C. for a two-year period, covering the calendar years 1951 and 1952, the agreement now in effect in regard to the publication of the Welding Research Supplement in THE WELDING JOURNAL, with exception that in Item 4 which now reads:

"The W.R.C. agrees to pay an additional $15.00 per page for each page above this number."

amended to read:

"The W.R.C. agrees to pay an additional $25.00 per page for each page above this number."

Report of Special Committee on A.W.S.-W.R.C. Relations

At a meeting of the Executive Committee of the SOCIETY on June 7, 1950, that Committee appointed a three-man Committee consisting of H. O. Hill, as Chairman, H. C. Boardman and T. C. Fethers-ton, for the purpose of reviewing and rendering report on the history of the Welding Research Council and its relationship with the AMERICAN WELDING SOCIETY as well as making suitable recommendations to the Board of Directors that Article XVI "Welding Research" of the SOCIETY's By-Laws be revised to reflect the true relationship between A.W.S. and W.R.C. as it exists today. This report to be rendered to the Board of Directors as part of this year's business and the Committee to be known as the "Special Committee on A.W.S.-W.R.C. Relations."

The "Special Committee on A.W.S.-W.R.C. Relations" accordingly made recommendation to the Board of Directors at this meeting regarding the proposed wording for Article XVI "Welding Research" of the SOCIETY's By-Laws. The Board of Directors upon motion, duly seconded, voted favorably to adopt the new wording for Article XVI and recommended its acceptance by the A.W.S. Constitution and By-Laws Committee.

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Herewith follows revised wording for Article XVI "Welding Research" of the Society's By-Laws:

WELDING RESEARCH

Section 1. Welding Research.—The American Welding Society shall provide for research in welding and the related processes as a Society and/or by cooperating with the separate research organization known as the Welding Research Council.

Section 2. Research Funds.—Research funds of the Society may be obtained through voluntary contributions, by solicitation or by appropriations from the regular funds of the American Welding Society. Solicitation of funds in the name of the Society may be made only with the approval of the Board of Directors.

Section 3. Custodian of Research Funds.—The Custodian of research funds of the Society shall be the American Welding Society or any other body designated by the Board of Directors.

Section 4. Research Publications.—A separate section of The Welding Journal of the American Welding Society may be provided for the publications of the Welding Research Council.

The Board of Directors voted favorably to discharge the "Special Committee on A.W.S.-W.R.C. Relations" with a vote of thanks for its submission.

Corporation Membership

In an endeavor to furnish industry with the activities it now seeks, L. C. Bibber, A. F. Davis and J. B. Tinnon went on record as favoring an additional membership classification, to be known as a Corporation membership.

Annual Report on Activities of the Society

An 18-page report on the activities of the Society for the administrative year ending Aug. 31, 1950, as prepared by the Society's Secretary, was submitted to the Board of Directors.

Time and Place of Next Meeting

The Board of Directors will hold its next meeting on Thursday, Oct. 26, 1950 in the Hotel Sherman, Chicago, Ill.

President Fraser announced that a meeting of the Executive Committee of the Society will be held sometime in September.

Adjournment

The meeting was adjourned at 4:20 P.M.

Executive Committee Meeting

A meeting of the Executive Committee of the American Welding Society was held in room 608, Engineering Societies Bldg., 33 W. 33rd St., New York, Thursday, Sept. 21, 1950 with the following in attendance:

Members: O. B. J. Fraser, *Chairman.* David Arnott, R. S. Donald, H. O. Hill and C. H. Jennings.
By Invitation: C. D. Evans.
A.W.S. Staff: J. G. Magrath.

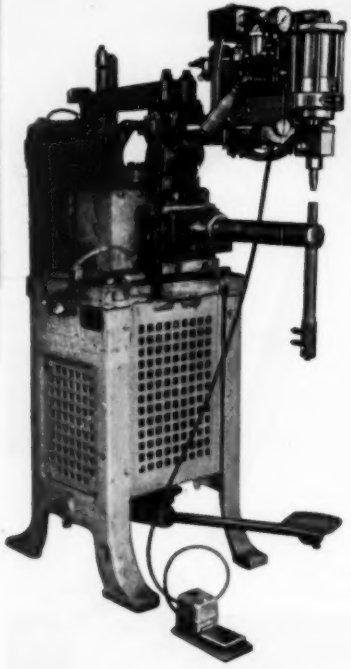
By-Laws Recommendations

The Constitution and By-Laws Committee met on Tuesday, Sept. 19, 1950. It was represented by its Member, H. O. Hill, who presented his Committee's recommendations which follow. Each recommendation was acted upon by the Executive Committee as indicated.

Report on Committee on Election Procedure

The viewpoints and recommendations of the Constitution and By-Laws Committee relative to the report rendered by the Special Committee on Election Procedure to the Executive Committee of the Society at meeting held on Apr. 26, 1950, are as follows:

1. The proposed method of selecting a Nominating Committee has practically been in effect for several years. It was criticized by the Sections and was revised about a year ago to its present form requiring the election of a Nominating Committee. This revised procedure has not even been tried to date and should not be changed for the present. The chief difficulty involved is that the members selected by the seven



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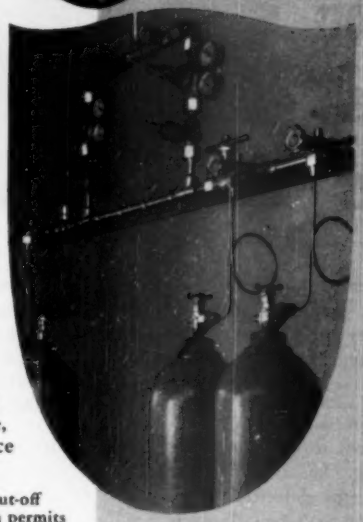

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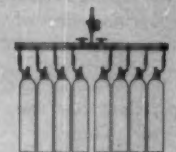

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Districts may not be acquainted with suitable officer material and they may not have the ability to pick men with suitable qualifications. This is a chance that will have to be taken for the present.

2. The second item requires that the Nominating Committee meet on or before a certain date. That is provided for at present by stating that the report of the Nominating Committee shall be submitted to the Secretary on or before May 10th. This gives a time schedule that must be followed.

3. The third suggestion is that the Nominating Committee publish the names along with the qualification and other information regarding the candidates. This Committee believes this is a very good suggestion which should be incorporated in the By-Laws. This might discourage further electioneering.

4. The fourth suggestion is to require 250 endorsements for additional nominees instead of the present 25. This Committee feels that 100 endorsements, as suggested by the Special Committee on Election Procedure, might encourage electioneering.

5. The fifth suggestion is to obtain similar information regarding the candidates by petition and publish in a subsequent issue of the JOURNAL. This Committee favors such action.

The Constitution and By-Laws Committee in an attempt to incorporate the suggestions they favor into the SOCIETY'S By-Laws recommend the following revisions:

ARTICLE XII

SECTION 7. *National Nominating Committee.*—Fourth sentence revise as follows: "The Committee shall deliver to the National Secretary in writing, on or before the 10th day of May of that year, the names of its nominees for the various elective offices next falling vacant with the written acceptance of each nominee. (District Vice-Presidents and District members of the National Nominating Committee shall be nominated by each District Nominating Committee. See Article VI, Section 6.) This Committee shall also obtain information and prepare a statement regarding the qualifications and other information regarding all candidates, except the candidates for the National Nominating Committee, of not less than one hundred and seventy-five (175) words nor more than two hundred (200) words which shall be submitted to the National Secretary for publication in THE WELDING JOURNAL and also on the ballots. (These reports shall cover candidates nominated by the National Nominating Committee, the District Nominating Committees and by letter ballot.)"

ARTICLE IX

SECTION 1. *Nominations.*—(*b*) The Secretary shall mail, on or before the first day of June of each year, to each member entitled to vote, a notice that nominations for officers must reach the Secretary not later than the first day of

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July. This notice shall outline the vacancies of elective offices that shall be filled at the next regular election and request nominations for such offices. This notice shall contain a copy of this Section and the list of nominees recommended by the National and District Nominating Committees with a statement regarding the qualifications and other information regarding each candidate (except candidates for the National Nominating Committee), as prepared by the National Nominating Committee. The notice shall also state that no other names shall appear on the final voting ballot unless proposed by at least one hundred (100) qualified Corporate Members. This notice shall also contain the names of the members of the National Nominating Committee.

SECTION 2. *Election.*—(*a*) If a member, not proposed by the Nominating Committees, is duly nominated as provided for in Section 1 of this Article, then the Secretary shall mail, on or before the 25th day of July of that year, to each member entitled to vote, a ballot stating the names of the candidates for the several offices falling vacant, with a statement regarding the qualifications and other information regarding each candidate (except candidates for the National Nominating Committee) as prepared by the National Nominating Committee. The time for the closure of the voting shall also be stated.

The ballot sheet shall list the names of the candidates proposed by the Nominating Committees and the respective offices for which they are candidates and the names of candidates nominated by letter ballot as provided in Section 1, Paragraphs (*b*) and (*c*), of this Article. Candidates selected by the Nominating Committees shall be identified by an asterisk.

Upon review of the foregoing recommendations the Executive Committee moved, seconded and voted approval based upon the following changes:

ARTICLE XII

SECTION 7: Change "10th day of May" to "1st day of May" and delete the words "less than one hundred and seventy-five (175) words nor."

Tellers of Nominations

In regard to the Society's Executive Committee recommendation that the Constitution and By-Laws Committee submit suggested by-law revisions allowing presidential appointment of "Tellers" for canvassing and certifying nominations ballots instead of present by-law procedure whereof the activity is the duty of the National Nominating Committee, the Constitution and By-Laws Committee report that in their opinion the same "Tellers" could function to canvass and certify both the nomination and, when such is necessary, the election ballots. Therefore that Committee recommended the following revision to the by-laws:

ARTICLE IX

SECTION 1. (*c*) The nomination ballots must be placed in a plain envelope and sealed; then inserted in a second envelope and sealed. The voter shall then sign his name thereon in ink and mail it to the Secretary. The Secretary shall certify to the competence and signature of all voters returning endorsed nomination ballots and shall then deliver them unopened to the Tellers of Election. See Section 7 of this Article.

A nomination ballot without autographic endorsement of the voter written on the outside envelope shall be considered defective and shall not be canvassed by the Tellers of Election. The Tellers shall first open and destroy the outer envelopes of all properly endorsed ballots, and shall then open the inner envelopes, canvass the ballots and certify the results to the Secretary. If no nominations, other than those proposed by the Nominating Committee, are made by one hundred (100) qualified members, then the Secretary shall treat the nomination ballots as Election Ballots and shall cast the ballot for the election of the candidates so nominated.

SECTION 7. *Tellers of Election.*—The President shall, on or before the first day of July, appoint three (3) Tellers of Election whose duty shall be to canvass the votes cast for nominees and when necessary, for election and shall certify the same to the Secretary. At the Annual Meeting this Committee shall certify to the President or to the Presiding Officer, the names of duly elected officers. Their term of office shall expire when their

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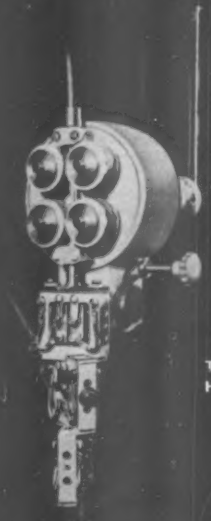

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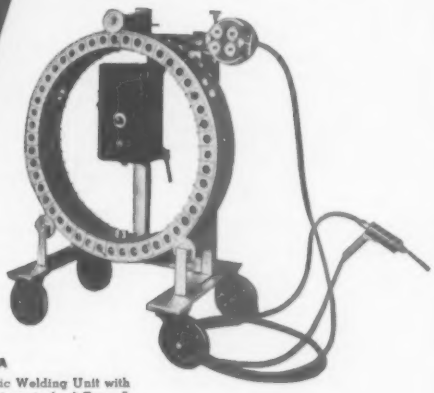

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The control is a self-contained unit with its own arc contactor for simplified wiring; just connect the welding machine cable to the arc contactor and plug in the control to the lighting circuit.

The head weighs only 38 pounds, has four driven rolls for positive feed without excessive wear or damage to wire coatings and 360° rotation with guide wheel—six mounting positions.

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report of the canvass has been presented and accepted.

ARTICLE XII

SECTION 7. *National Nominating Committee.*—Delete the last sentence which reads, "This Committee shall also canvass the nomination ballots and certify the result to the National Secretary."

Upon review of the foregoing recommendations the Executive Committee moved, seconded and voted approval of all as submitted.

Life Membership

As a result of previous action taken by the Board of Directors on granting of life membership to Past-Presidents of the SOCIETY, the Constitution and By-Laws Committee recommend the following revisions to the by-laws to comprehend life membership for A.W.S. Past-Presidents:

ARTICLE I—MEMBERSHIP

SECTION 1. *Classes of Members.* Add —F—Life Members."

SECTION 2. *Qualifications and Privileges.* Add "F—Life Members: A Life Member shall be (1) one who has served as National President of the SOCIETY for at least one (1) year; (2) any Member or Associate Member who shall have paid his dues for thirty-five (35) years, or who having paid his dues for thirty (30) years and having reached the age of sixty-five (65) years, except that the number of years for which dues were paid as an Associate Member shall be reckoned as nine-tenths (9/10) of their number in the above provisions. Life Members shall have rights of full membership. (Student Membership years not included.)"

SECTION 3. *Corporate Members.* Add "F."

ARTICLE IV—DUES AND FEES

SECTION 1. *Amount of Dues.* Add—"(F) Life Members . . . . . None."

Omit SECTION 4. CANCELLED DUES.

Renumber Sections 5, 6 and 7 to 4, 5 and 6.

Upon review of the foregoing recommendations the Executive Committee moved, seconded and voted approval based upon the following revised text:

ARTICLE I—MEMBERSHIP

SECTION 1. *Classes of Members.* Add—"F—Life Members."

SECTION 2. *Qualifications and Privileges.* Add "F—Life Members. A Life Member shall be one who has served as National President of the SOCIETY for at least one (1) year. Life Members shall have rights of full membership. (Student Membership years not included.)"

SECTION 3. *Corporate Members.* Add "F."

ARTICLE IV—DUES AND FEES

SECTION 1. *Amount of Dues.* Add—"(F) Life Members . . . . . None."

The Constitution and By-Laws Committee at its meeting on Tuesday, Sept. 19, 1950, acted as follows:

1. To recommend to the A.W.S. Board of Directors that the Board make a ruling to the effect that "The Board of Directors discourage the dissemination of electioneering literature regarding candidates for National Office except that prepared and published by the National Nominating Committee, as provided for in the SOCIETY's By-Laws, and that this statement accompany publicity submitted by the National Nominating Committee both in THE WELDING JOURNAL and on the election ballot."

The Executive Committee approved of the foregoing recommendations and referred it to the Board of Directors for consideration and action.

The Constitution and By-Laws Committee at its meeting on Tuesday, Sept. 19, 1950 acted as follows:

2. Approved wording for Article XVI, "Welding Research," of the SOCIETY's By-Laws as prepared by Special Committee on A.W.S.-W.R.C. Relations and as approved by the Board of Directors at meeting held on Aug. 29, 1950. Voted favorably that the revised by-law be submitted to the membership-at-large for final approval.

3. Approved wording for Article XII, Section 3, "Membership Committee" of the SOCIETY's By-Laws as revised by the Executive Committee of

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East Chicago, Ind.

the SOCIETY at meeting held on Jan. 24, 1950. Voted favorably that the revised by-law be submitted to the membership-at-large for final approval.

4. Approved wording for Article V, Section 2, "Minimum Section Membership," and Section 6, "Requirements of an Active Section," of the SOCIETY's By-Laws as revised by the Executive Committee of the SOCIETY at meeting held on Jan. 24, 1950. Voted favorably that the revised by-law be submitted to the membership-at-large for final approval.

Progress Report on Annual Meeting Plans

The Secretary of the Convention Committee, J. G. Magrath, reported that the Convention Committee met in Chicago on Sept. 15, 1950, and that the plans are progressing in good order in Chicago under the general direction of Homer Morrison, Chairman, and E. P. Auler, Vice-Chairman, at Chicago. The Chicago subcommittee groups are well organized and proceeding in proper timing with their functions. The Secretary submitted a recommendation made by William Spraragen, JOURNAL Editor that all *registering* nonmembers at our Annual Meeting be presented a slip entitling them to $1.00 credit against their purchase of A.W.S. membership providing that their application was received at National Headquarters within thirty (30) days from closing date (October 27th) of the National Meeting. It was moved, seconded and voted approval of this recommendation and the Secretary was directed to institute the necessary procedure.

Headquarters Housing

R. S. Donald, Chairman of the Headquarters Housing Committee, reported that he and the SOCIETY's Secretary had examined a number of houses in the New York City Murray Hill and near-by area for the purpose of A.W.S. housing its headquarters in its own property and effecting housing cost savings. To date but one property was disclosed which has possibilities, a property at 238 E. 62nd St., reported to be available at around $45,000 cash price. Detailed exploration is to be made within several days for assurance that the property has ample floor area for A.W.S. present and near future expansion needs. The general discussion by the Executive Committee was to the effect that all possible angles should be explored carefully, such as added costs of maintenance, heating, light and power, caretaking, telephone service, repairs, insurance, depreciation, loss of interest on moneys appropriated for purchase, interest charge on loans negotiated for purchase, transportation convenience and other facilities and services now enjoyed by A.W.S. under its present housing arrangements. The Headquarters Housing Committee was asked to prepare and present a proposed plan for financing of this project.

Correspondence Welding Course

The Secretary reported that R. M. Gooderham, Managing Director of the Canadian Welding Bureau and proposer of an A.W.S. Correspondence Welding Course modeled on the pattern of the reportedly successful Canadian Welding Bureau Correspondence Welding Course, met with O. B. J. Fraser, *President*, R. S. Donald, *Treasurer*, E. Holloway, A.W.S. Legal Counsel and J. G. Magrath, *Secretary*, on Sept. 12, 1950, in New York City. It was pointed out to Mr. Gooderham by Mr. Holloway that Mr. Gooderham's proposed agreement did not afford the SOCIETY sufficient protection in case of cessation of Mr. Gooderham's interest or participation in the activity. Mr. Gooderham suggested that Mr. Holloway rewrite the agreement with those provisions he felt necessary for the SOCIETY's protection. Mr. Gooderham stated that the present international situation, one of neither full peacetime or full wartime activity, was resulting in much industrial uncertainty. Many large American industries are uncertain, as of today, what will be their activity six months from now and shall they be able to secure materials to pursue their present activity. Hence he feels that we should delay introduction of the course at this time. He suggests deferment of action for a period of several months until events have indicated the path of American industrial activity. He believes, that the cited uncertainty, on both individuals' and industries' parts, would result in lack of acceptance of a correspondence welding course at this time. Further action, other than preparation of revised proposed agreement, is deferred for approximately two months.

T.A.C. Recommendations for Enlargement of Technical Activities

The Executive Commitee moved, seconded and voted that the proposal for extension of T.A.C. activities, which included the engagement of an assistant for the Technical Secretary, be brought before the next Board of Directors Meeting at the joint 1949–50 and 1950–51 Board of Directors Meeting in Chicago on Thursday, Oct. 26, 1950; the 1949–50 Board Members to review the T.A.C. proposals and to recommend action to the 1950–51 Board Members at the same joint meeting.

The Executive Committee moved, seconded and voted that the Technical Activities and the Finance Committees should appoint representatives of each committee to a joint special committee whose scope would be the devising of a program designed to secure funds from industry for supporting Technical Activities; program to be similar to that conducted by the Society of Automotive Engineers and other comparable fund-seeking programs by engineering Societies.

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NEWS OF THE INDUSTRY

Nondestructive Testing

The Society for Non-Destructive Testing held its technical meetings at the Morrison Hotel, Chicago, Ill., Oct. 24, 25 and 26 1950. The Society is one of the four technical societies which sponsor the National Metals Congress.

The program was made up of papers on a wide variety of nondestructive testing subjects presented by recognized authorities in their fields. Emphasis was being placed on the latest techniques, including the use of Radio-Isotopes, ultrasonic and magnetic testing methods. Two papers were of special interest to members of the Society. These are:

"Magnetic Particle Inspection of Welded Pipe and Tubing," J. E. Clarke, V.-P. Research; R. A. Peterson, T. Dunsheath, Research Engineers, Magnaflux Corp., Chicago.

"Symposium on Magnetic Particle Testing," Wm. C. Hitt, *Chairman*, Asst. Chief Inspector, Douglas Aircraft Co., Santa Monica, Calif.; M. B. Hoffman, Methods Engineer, Sawbrook Steel Castings Co., Lockland, Ohio; A. C. Richmond, Gen Supt., Inspection Methods Research, International Harvester Co., Chicago, Ill.; and Charles Ziegler, Chief Inspector, Marion Power Shovel Co., Marion, Ohio.

Resistance Welder Sales Continue to Climb

Statistics compiled by the Resistance Welder Manufacturers Association based on reports from all of its members show that the sales of resistance welding machines continue to soar. Net orders received during the first seven months of this year as compared to the same period in 1949 show a jump of 69%.

International Welding Congress

The International Institute of Welding in collaboration with its British member societies, is organizing an International Welding Congress in London and Oxford, July 14–21, 1951.

Attendance at the Congress is not restricted to members of the Governing Council.

Copies of the provisional program and enrollment form may be obtained through the International Institute of Welding, 2, Buckingham Palace Gardens, London, S.W.1, England.

Enrollment closes December 31st.

Any member desiring to submit a paper on one of the following two subjects is requested to notify the office of the AMERICAN WELDING SOCIETY: "Welding of Bridges and Structures"; "Welding of the Wrought Light Alloys."

R.W.M.A. Continues Research Contributions

A further contribution to the Welding Research Council has just been made by the Resistance Welder Manufacturers Association to continue a projection welding research program at R. P. I.

Welding Instruction for Defense Employees

Another important step in its "Welding for Defense" program was made by Eutectic Welding Alloys Corp. of New York when it was announced that enrollment in the Eutectic Welding Institute, at the company's plant in Flushing, Long Island, is being extended without charge to employees of Government agencies and to members of the Armed Services.

The next class at The Eutectic Welding Institute is scheduled to open early in October. Inquires regarding enrollment and instruction should be directed to the Technical Information Service, Eutectic Welding Alloys Corp., 40 Worth St., New York 13, N. Y.

$25,000 Awards: Agriculture Award and Scholarship Program

Farm mechanization, and with it farm arc welding, is rapidly reaching into all corners of the United States if the recently announced results of the Lincoln Arc Welding Foundation's Agricultural Award Program can be taken as an indication.

The 141 awards totaling $20,000 given to farmers, county agents, teachers and other agricultural leaders went to men and women in 43 out of the 48 states. The program offered awards ranging from $50 to $1755 for the best descriptions of how arc welding is used on the farm to improve farming methods. Men and women in all types of farming activities described the arc welded repair or construction of farm machinery or structures.

In honor of the top ten award winners in each Division of the program, scholarship funds totaling $5000 have also been given by the Foundation to the colleges of agriculture in the states in which they reside. The funds will be used by the colleges to grant scholarships in the names of the award winners.

The $1500 first award in Division I of the program for farmers went to Armin and Kenneth Garver of Youngstown and Poland, Ohio, who with their father farm 300 acres of land, raising grain, poultry, berries and popcorn.

The $1755 first award in Division II for agricultural leaders was given to Professors Albert Mowery and David McClay of the Pennsylvania State College. They are professors of agricultural engineering and agricultural education, respectively.

The second award of $1000 in Division I was awarded to Elgar Schroeder of Morrisonville, Wis. Schroeder, who won first award in the 1946 First Agricultural Award Program, operates a 130-acre farm with his father raising beef cattle, hogs and poultry. They raise their own feed on a well mechanized basis.

Kenneth Imig of Watseka, Ill., farm adviser for Iroquois County, took the second award of $1170 in Division II for his paper describing how farmers in his county have repaired and made useful farm machinery.

The awards for Division II were slightly larger than those for Division I since the Jury of Award vacated several awards in Division II and the full $10,000 was apportioned among those receiving awards.

According to Dr. E. E. Dreese, Head of the Department of Electrical Engineering at The Ohio State University and Chairman of the Jury of Award:

"An index of the descriptions of farm-made projects entered in this program reads like a farm machine and tool catalog. Everything from 8-tined pitch forks to peanut harvesters are described. The wide variety of projects submitted in the competition not only indicates the extent to which modern farming has become mechanized, but also proves that the American farmer's ingenuity is equal to any task he sets for himself. It is this ingenuity that keeps agriculture in pace with industry in the constant effort to become more efficient and arc welding is the means by which many farmers are able to exercise that ingenuity."

This program is the second which the Lincoln Foundation has sponsored to stimulate the study of how the industrial process of arc welding can contribute to the advance of the science of farming.

The Jury of Award, headed by Dr. E. E. Dreese of The Ohio State University, consisted of:

E. W. Schroeder, Head, Agricultural Engineering, Oklahoma A. & M. College.
V. J. Morford, Professor, Agricultural Engineering, Iowa State College.
J. W. Martin, Head, Agricultural Engineering, University of Idaho.
A. H. Hollenberg, Specialist, Agricultural Extension Service, U. S. Office of Education.
Kyle Engler, Head, Agricultural Engineering, University of Arkansas.
H. H. DeLong, Head, Agricultural Engineering, South Dakota State College.
Carl Albrecht, Assistant Professor, Agricultural Engineering, Michigan State University.
O. C. French, Head, Department of Agricultural Engineering, Cornell University.
F. C. Fenton, Professor, Agricultural Engineering, Kansas State College.

PERSONNEL

C. E. Wilson, President, General Motors, Receives A.S.M. Medal for the Advancement of Research

Charles E. Wilson, President, General Motors Corp., received the American Society for Metal's 1950 Medal for the Advancement of Research during the 32nd Annual National Metal Congress and Exposition in Chicago, October 23–27. Mr. Wilson was the eighth distinguished scientist-industrialist to receive the honor, established in 1943 to recognize the industrial executive who, over a period of years, has consistently sponsored metallurgical research or development and, by his foresight and his influence in making available financial support, has helped substantially to advance the arts and sciences related to metals.

Award of the medal, plaque and citation were made at the annual banquet of the American Society for Metals in the Grand Ballroom of the Palmer House, Chicago, Thursday evening, Oct. 26, 1950.

The seven previous recipients of the Research Medal are: Roy A. Hunt, President, Aluminum Co. of America, 1943; Robert C. Stanley, President, International Nickel Co., 1944; Gerard Swope, General Electric Co., 1945; Dr. Rufus E. Zimmerman, Vice-President, United States Steel Corp., 1946; Charles R. Hook, President, The Armco Corp., 1947; W. H. Dow, President, Dow Chemical Co., 1948; Fred H. Haggerson, President, Union Carbide and Carbon Corp., 1949.

Wendell Hess Wins Miller Medal

The Jury of Awards has selected Dr. Wendell F. Hess of Rensselaer Polytechnic Institute as the recipient of the 1949 Samuel Wylie Miller Memorial Medal and Certificate. Dr. Hess is well known to the members of the AMERICAN WELDING SOCIETY. He is a relatively young man to have won so many awards and designations as he was born on Jan. 1, 1903.

Dr. Hess served the SOCIETY long and well. He became an Associate Member in 1929, a Member in 1938 and was made an Honorary Member in 1948. He was Chairman, Northern New York Section; District Vice-President, New York and New England; National 2nd Vice-President, 1944–45; National President, 1945–46; Member of Board of Directors, 1944 to 1949.

Dr. Hess is a member of many other societies including the Electrical Engineers, Mining and Metallurgical Engineers, A.S.T.M., A.S.M., A.S.E.E. and the Franklin Institute.

Most of Dr. Hess's professional experience relates to R.P.I. He served as instructor in Electrical Engineering from 1928–30. For the next seven years he served as Assistant Professor of Electrical Engineering and Physics. In 1937 he switched over and became Assistant Professor in Metallurgy and Engineering at R.P.I. He rose to Associate Professorship and Head of the Welding Laboratory in 1938. He was made a full Professor in 1945. In 1947 he was made Head of the Department of Metallurgical Engineering, a position which he still holds. In addition to the Miller Medal Dr. Hess has won the following awards: 1944 Lincoln Gold Medal; University Award of the Resistance Welder Manufacturers Association 1944, 1945, 1946, 1947 and first and second prizes 1948; 1945 American Iron and Steel Institute Medal and the 1948 John Price Wetherill Medal of the Franklin Institute.

L. H. Carr Named Head of Engineering and Research

Laurence H. Carr has been named director of engineering and research for Edward Valves, Inc., East Chicago, Ind.

Mr. Carr has been a member of the Edward technical staff since 1936. He was previously chief metallurgist. In his new position he will be responsible for consolidating the development functions of engineering research, product engineering and technological specifications for process control.

A graduate of the University of Chicago, Mr. Carr is a member of the American Society of Mechanical Engineers, American Society for Metals, American Institute of Mining and Metallurgical Engineers, AMERICAN WELDING SOCIETY and American Foundryman's Society.

An authority on metals for high-pressure and high-temperature service, he has been an active member of such specification and standardization groups as the American Society for Testing Materials, American Standards Association and the American Petroleum Institute. He is also known as an authority on the characteristics of flow through piping.

Mr. Carr is a resident of Homewood, Ill.

Avery Wins Lincoln Gold Medal

The Committee on Awards selected the paper on "Hot Hardness of Hard-Facing Alloys," by Howard S. Avery, American Brade Shoe Co., Mahwah, N. J., published in the July 1950 issue of THE WELDING JOURNAL, as the paper representing the greatest contribution to the advancement and the use of welding for the year 1950. Mr. Avery thus becomes the recipient of the 1950 Lincoln Gold Medal Award.

Howard S. Avery was born in Canon City, Colorado, in 1906. Moving to Virginia at the age of eleven, he went through high school in Roanoke and college at Virginia Polytechnic Institute. In 1927 he received a B.S. degree and returned to Virginia Tech to hold a teaching fellowship the following year while taking postgraduate work. In 1928 he received an Engineer of Mines degree with honors.

Howard S. Avery

Following several years of mining engineering and geology in Mexico, steel mill experience and teaching, he joined the newly organized Metallurgical Department of the American Brake Shoe Co. in 1934. Since then he has been identified with this company's research in various aspects of industrial wear.

He married Louise Steele of Roanoke, Va., in 1931. They are raising a family of four children. Nonprofessional activities include supervising a junior rifle club and training Boy Scout leaders.

Heat- and wear-resistant alloys have engaged a large share of his attention. His efforts to define the engineering properties of the most important industrial cast heat resistant alloys are reflected in a series of technical publications. For years he has been a member of the Alloy Casting Institute Technical Research Committee, which guides cooperative research of the alloy casting industry, and from 1947 to 1948 was Chairman.

Abrasion testing and the relative performance of the many alloys used to resist wear, from very tough austenitic manganese steel to the very hard martensitic irons, have been fields of continual study. This has naturally involved their use as welded overlays, which has received increasing attention because of his faith in the potential value of the hard-facing technique to industry. As research metallurgist for the American Brake Shoe Co. he is now actively planning and supervising research in this area.

Professional society affiliations include the AMERICAN WELDING SOCIETY, The American Society for Metals, The Metal Science Club, The American Institute

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of Mining and Metallurgical Engineers and the British Iron and Steel Institute. He has served on various specification, program and educational committees; is currently on the A.S.M. Handbook Committee and the Welding Research Council High Alloy Committee. He contributed to the *1950 Welding Handbook* and is now Chairman of the A.W.S. Filler Metal subcommittee on Hard-Facing Alloys.

Biographical Sketches— R.W.M.A. Prize Winners

Joseph W. Kehoe

Joseph W. Kehoe, winner of the first prize of $750 for the best paper from an industrial source in the 1950 Resistance Welder Mfgrs. Assn. Contest, is Section Engineer in charge of the Metals Joining Section of the Headquarters Mfg. Eng. Dept., Westinghouse Electric Corp. He was born in Conshohocken, Pa., and is a graduate of Villanova College, Class of 1934, with a B.S. Degree in Electrical Engineering. He is a member of the Board of Governors of his Alma Mater and is also President of the Pittsburgh Villanova Alumni Club.

Joseph W. Kehoe

Mr. Kehoe joined the Westinghouse Electric Corp. as an electrical tester in June 1936. His interest in welding brought him into the Headquarters Mfg. Eng. Dept. in 1939, where he quickly became associated with metals joining activities, specializing in resistance welding development work. This department is the central metals joining development agency of the Westinghouse Corp., and its welding laboratory is located in the East Pittsburgh Works. Mr. Kehoe is also Chairman of the Metals Joining Committee of the Corp.

Several resistance welding articles have been written by Mr. Kehoe but this is the first entry in the Annual Resistance Welder Mfgrs. Assn. Contest. He also holds a patent on projection welding.

Mr. Kehoe is a member of the Pittsburgh Section of both the AMERICAN WELDING SOCIETY and the American Institute of Electrical Engineers. He is also a member of Toastmasters International, Club 144, Pittsburgh, Pa.

Axel O. Bergholm

Mr. Bergholm received his B.S. in Civil Engineering in 1927 from Pennsylvania State College and had one year of postgraduate study in structures and mathematics at M.I.T.

For seven years as a Research Engineer at The Franklin Institute Laboratories for Research and Development, Mr. Bergholm has worked on the analysis and design of numerous artillery weapons. Various industrial projects were worked on, such as structural testing, photoelastic problems, dynamic analysis of test data of machines and design of machines.

Mr. Bergholm was a test engineer at The Budd Co. for five years. He was responsible for stress analysis and planning, supervision and construction of static test equipment for testing stainless steel wing for a P-35 airplane. He planned and supervised design of test equipment for a railcar test plant and supervised the structural testing of numerous railcars. He also planned and tested structural components of the B-1 and B-36 airplanes.

Mr. Bergholm was Research Assistant to Professor G. E. Beggs of Princeton University for one year. This work included the design, construction and testing of a stainless steel model of a floating dry dock for the U. S. Navy to verify the design and analysis of the 1200-ft. prototype.

In addition to the above, Mr. Bergholm's engineering experience includes the following:

Construction Engineer for the Triborough Bridge Authority of New York for one year, in charge of construction of anchorages, steel erection and road construction of a suspension bridge over Hell Gate in New York Harbor.

Axel O. Bergholm

Consulting Engineer for the Republic of Haiti for one year on design of the tower foundations and anchorages of a suspension bridge including supervision of construction of the entire bridge. This bridge was built over the Guauamoue River in the interior of Haiti.

Junior Engineer for the Port of New York Authority for three years, in which capacity he worked on the construction of the George Washington Bridge as engineer in charge of steel construction, concrete construction of foundations and roads, construction surveys, triangulation surveys, cable construction and cable calculations. He also designed, constructed and experimented with an elastic model of the bridge to determine deflection for various methods of erection.

Research Assistant for the Port of New York Authority for one year performing mechanical analysis of sand and gravel, organic tests of sand, physical and chemical tests of cement, research in the proportioning of concrete mixes from which water-cement ratio curves and fineness modulus curves were developed, physical testing of paint, steel, cable, structural columns and concrete. He designed a physical testing laboratory including cement, concrete and chemical laboratories, machine shop and constant temperature and humidity rooms.

Mr. Bergholm is a Registered Professional Engineer in Pennsylvania and New York and is now Senior Research Engineer, Engineering Mechanics Section, Franklin Institute.

He is a member of the honorary society Tau Beta Pi. He is one of the co-authors of the second prize winning paper in the R.W.M.A. prize contest from an industrial source.

Paul W. Swartz

Mr. Swartz, Research Engineer, Mechanical Engineering Section Franklin Institute, received his B.S. degree in Mechanical Engineering in 1945 from M.I.T.

For four years, Mr. Swartz has been employed in The Franklin Institute Laboratories for Research and Develop-

Paul W. Swartz

ment in the capacity of Technical Assistant and Research Engineer on various industrial projects, mainly in the role of experimental stress analyst using photoelastic methods, brittle lacquers, electrical strain gages, and visual flow investigations. Experimental tests on commercial products and methods have also been performed. He has also worked on the analysis and design of artillery weapons.

Mr. Swartz spent three years in the United States Navy and was released from active duty with the commission of Ensign. He performed duties as Deck Officer and Assistant First Lieutenant aboard the U.S.S. *Botetourt*. He is now a member of a naval research unit under the authority of the Office of Naval Research.

Mr. Swartz is a member of the Society for Experimental Stress Analysis and is one of the co-authors of the second prize winning paper in the R.W.M.A. prize contest from an industrial source.

George S. Hoell

George S. Hoell, Consultant, The Franklin Institute Laboratories for Research and Development was born in Skien, Norway, Nov. 6, 1878. He received his technical education at the Trondheim Technical College (Norway), a four-year course in Mechanical Engineering. After about two years of machine shop training and drafting room experience in a shipyard in Norway, he came to Philadelphia in 1902. Following two years at Midvale Steel Co. and three years as chief draftsman at the George V. Cresson Co., he entered into a business with a friend and after a short time specialized in the design and construction of hydraulic dredging machinery. He disposed of his interests in this venture after 11 years, and at the outset of World War I was one of the organizers of the Pennsylvania Shipbuilding Co. with yards at Gloucester, N. J. He served as that company's treasurer and secretary for two years, until it was amalgamated with the Pusey & Jones Co.

He organized the Gloucester City Trust Co. as an aid in handling the payroll of the shipyard and served as the Trust Company's president the first year.

George S. Hoell

After serving four years as mechanical engineer and later as consultant for the Pennsylvania Crusher Co., Mr. Hoell was incapacitated by illness for nearly three years. He then took on private consultation work, following which he entered the Budd Mfg. Co. as a machine designer. From there he was called to The Franklin Institute to serve in the Civil Service as an Ordnance Engineer in the employ of the U. S. Ordnance Department, later as chief engineer of the Artillery Development Suboffice located at The Franklin Institute, and received the War Department's "Commendation for Meritorious Civilian Service" for his performance in that position.

Mr. Hoell is a member of the American Society of Mechanical Engineers and The Franklin Institute, and is a registered professional engineer.

Mr. Hoell is married to the former Lilly Clason of Porsgrunn, Norway, has three daughters, two sons, and eight grandchildren. He lives at 449 W. Bringhurst St., Germantown, Philadelphia, Pa. Mr. Hoell is co-author of the paper winning second prize in the R.W.M.A. contest for best papers from an industrial source.

I. S. Goodman

I. S. Goodman winner of the third prize from an industrial source in the R.W.M.A. prize contest is Welding Engineer, Chemical and Metallurgical Engineering Dept., Lamp Division, Westinghouse Electric Corp., Bloomfield, N. J.

I. S. Goodman

He resides at 72 Branch Brook Drive, Belleville, N. J.

Mr. Goodman was born Sept. 17, 1919 in New York City. He obtained his B.S. degree in physics from City College of New York (1939), his M.S. (physics & education) City College (1941). He undertook further graduate work in metallurgy at Stevens Institute of Technology.

Mr. Goodman is author of several papers and technical articles on metal joining techniques. He is instructor for Westinghouse Graduate School program on "Theory and Practice of Metal Joining."

Mr. Goodman is a Member of the AMERICAN WELDING SOCIETY, American Physical Society, American Society for Metals and American Institute of Mining and Metallurgical Engineers.

Professor Georges Welter

Since 1941, Professor Georges Welter has been connected with the École Polytechnique, affiliated with the University of Montreal, where he has developed two new well-equipped research laboratories for Metallography and Testing of Materials.

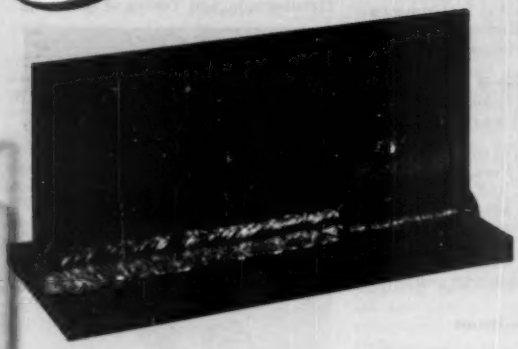
Prof. Georges Welter

In 1947, he won the first prize in the international contest "Design for Progress" of the James F. Lincoln Arc Welding Foundation; Division: Research and Education in College or University. This work has been published in the July 1948 Research Supplement of the AMERICAN WELDING JOURNAL. Besides the score of other scientific publications, he has worked, during the last few years, on the amelioration of spot welds, new methods for testing specimens under balanced triaxial tests and for testing steel vessels under very high hydraulic, static and dynamic pressure. A paper on his spot welding research won the first prize for the University Awards.

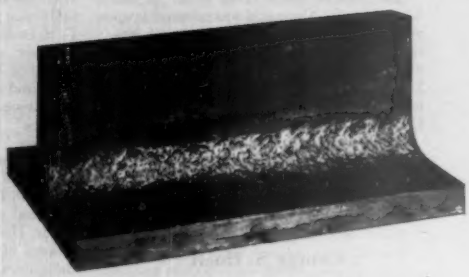
William Bennett Kouwenhoven

William Bennett Kouwenhoven received his Bachelor of Engineering degree from Brooklyn Polytechnic Institute in 1906 and his Master's degree a year later. He then attended the Karlsruhe Technische Hochschule in Baden, Germany, from which he was graduated with the degrees of Diplom Ingenieur and Doktor Ingenieur. In 1914 he obtained an instructorship at The Johns Hopkins University in Baltimore, and since 1930 he has been Professor of Electrical Engineering and Dean of the School of Engineering. Dr. Kouwenhoven is a member of the AMERICAN WELDING SOCIETY, American

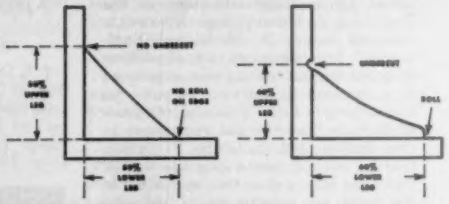
3 New Sureweld® Electrodes



Note unusual absence of spatter along uncleaned portion of this typical weld made with the new Sureweld "G". Note smooth finish of bead where slag has been removed.



Unretouched photograph of characteristic weld made with Sureweld "FD" showing smooth bead.



Sureweld "FD" Electrode **Most other "Hot Rods"**

1 GENERAL-USE

NEW *Sureweld* "G" (AWS E6012) ELECTRODE

This new general-use electrode is winning popularity for welds that are smooth, clean and good-looking. Absolutely odorless, the Sureweld "G" gives more inches of bead per rod, and is ideal for "stretching it out" . . . Give it a try, and you too will prefer it for all-position, general purpose welding. (Many users now choose Sureweld "G" in preference to the more expensive E6013 rods.)

1. Cleans easier.
2. Adaptable to "drag" technique.
3. "Spray-type" metal transfer (not "globular") for smooth-looking welds.
4. More inches of bead per rod.
5. Less spatter *than any other rod in the E6012 Class.*
6. Smooth arc-action and easy handling insure instant "welder appeal".

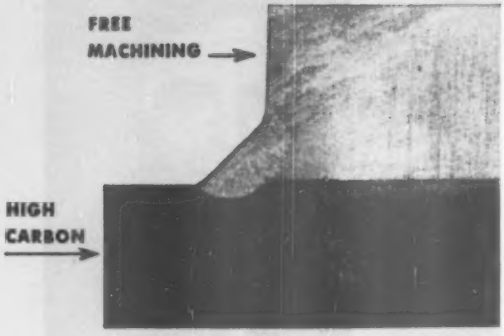
2 HIGH-SPEED

NEW *Sureweld* "FD" (AWS E6020) ELECTRODE

For highest quality deep groove and horizontal fillet welds, the new Sureweld "FD" is the answer. It's the fastest "downhand rod" in the business, as one trial will quickly prove. The coating will not break down under abusive heats, and you can get sound welds from the shortest stub you can hold. For best results in flat position welding, try the new Sureweld "FD".

1. Excellent cleaning properties.
2. Absence of spatter.
3. Bead appearance is almost ripple-free.
4. *No* excess fluidity, *no* undercutting. Fillet welds have legs of equal length.
5. Wash-back of arc-stream is so spaced that the bead is always covered with slag of uniform distribution and density.
6. Takes unusually high heats.

.... winning instant preference!



Excellent fusion of hard-to-weld metals is shown in this macrograph of a typical weld made with the new Sureweld "7016" electrode.

3 LOW-HYDROGEN

NEW *Sureweld* "7016" (AWS E7016) ELECTRODE

Because it produces welds of minimum hydrogen content, Sureweld "7016" has proved without equal for welding free-machining types of steel, the air-hardening types with an alloy content or high carbon, and other hard-to-weld steels. There is absolutely *no* underbead cracking, and welds made with "7016" have beads that feather equi-distantly from the joint. ("7016" is replacing the more expensive stainless steel types.)

1. *No* cracking, even with the hardest-to-weld steels, when properly used.
2. Welds contain less hydrogen *by test*.
3. No excess fluidity. Bead is symmetrical. Average welders become experts when they use "7016".
4. High deposition rate saves working time.
5. High efficiency—more pounds of weld metal per pound of electrode—saves money.
6. "Welder appeal" results from soft arc, low spatter and easier starting.
7. Impact strength—proved greater in Charpy tests at temperature readings as low as 100°F.

Designed by NCG, and proved in use, to meet three basic welding needs

Here's a threesome of new, improved welding rods that's meeting with enthusiasm in shops everywhere. Developed by NCG research, and proved in field use, these electrodes bring new advantages to three important classes of welding.

Write for the new Sureweld Catalog for complete information on these, and other performance-proved Sureweld Electrodes. Sureweld Electrodes are manufactured under the strictest controls in one of the world's most modern electrode manufacturing plants.

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William B. Kouwenhoven

Society for Testing Materials, Fellow A.I.E.E., and other societies. His principal endeavors have been in the fields of electric shock, welding and measurements. Dean Kouwenhoven is one of the co-authors of the second prize winning paper in the R.W.M.A. prize contest from a University source.

W. T. Sackett, Jr.

W. T. Sackett, Jr. was born in Xenia, Ohio on Jan. 28, 1921. He received the degree of Bachelor of Engineering in Electrical Engineering in June 1941 from the Johns Hopkins University.

Shortly thereafter he began work at the Duquesne Light Co. of Pittsburgh, Pa. under the supervision of George B. Dodds. In February of 1942 he left to work at the Naval Ordnance Laboratory in Washington, D. C. on the design of electronic equipment.

W. T. Sackett, Jr.

A Naval Reserve commission in 1944 led to overseas duty in the Pacific area after which he resumed work in the VT Fuze Division of NOL.

In the fall of 1947 he was granted leave of absence for graduate study at the Johns Hopkins University. He also acted as Instructor in Electrical Engineering. The Resistance Welding Fellowship was awarded to him for 1948–50. He received the degree of Doctor of Engineering in 1950.

He is currently working in the field of magnetic materials at Battelle Memorial Institute under Dr. R. C. McMaster.

Mr. Sackett is an associate member of the American Institute of Electrical Engineers and a member of Tau Beta Pi and Sigma Xi. He is co-author of the second prize winning paper in the R.W.M.A contest from a University source.

Keyser Promoted

At the University of Massachusetts, Dean George A. Marston recently announced the promotion of Assistant Professor Carl A. Keyser to the rank of Associate Professor of Metallurgical Engineering. Professor Keyser received the B.S. degree in Chemistry in 1939 from the Worcester Polytechnic Institute. This was followed in 1941 by receipt of the M.S. degree from the same institution.

Following this, Professor Keyser spent five and a half years in the Navy, and received a B.S. degree in Metallurgical Engineering from the Carnegie Institute of Technology in 1946.

He is in charge of Metallurgy service courses for Mechanical and Industrial Engineering Majors at the University of Massachusetts, and in addition instructs in courses dealing with materials engineering and testing.

Prof. Keyser is the Chairman of the Western Massachusetts Section of the AMERICAN WELDING SOCIETY, and Technical Representative of the same Section.

OBITUARY

W. B. Horton

W. B. Horton, welding engineer for Lincoln Electric in Chicago, Ill., died Sept. 19th. Mr. Horton, who was 53, started with Lincoln in 1929 in Chicago and was active in that area until the present engineering welding applications. Prior to his connection with Lincoln, he worked for several Chicago concerns, the Bristol Co. in Waterbury, Conn., and the Halle Bros. Co. in Cleveland. He was a member of the AMERICAN WELDING SOCIETY, and a Director of the Abraham Lincoln National Republican Club.

OBITUARY

Dr. John C. Southard

Dr. John C. Southard, A.W.S. Sustaining Member, Director of Research for Solar Aircraft Co., San Diego, Calif., died September 4 at the age of 43.

Dr. Southard was serving his first year on the N.A.C.A. subcommittee on Aircraft Structural Materials and was actively associated with the A.W.S., A.S.M., A.I.M.E., A.P.S., A.S.T.M., A.C.S. and Electrochemical Society. Author of 18 technical papers, he contributed chapters of text and illustrations to the recently published book in the Pitman Metallurgy Series, *Titanium in Steel*. He came to Solar in 1946 from the Titanium Alloy Mfg. Co., Niagara Falls, N. Y., where he had been chief process metallurgist. His Ph.D. in Physical Chemistry was from Johns Hopkins University; his B.S. from Baldwin Wallace College, Berea, Ohio.

Born in Willard, Ohio, Sept. 14, 1906, Dr. Southard's residence at the time of his death was 4827 Beaumont Road, La Mesa, Calif.

Employment Service Bulletin

Position Vacant

V-247. Position Available. Recent engineering graduate (preferably mechanical) with some practical welding experience to coordinate nonferrous welding research, development and manufacturing. Location—Middle West.

NEW LITERATURE

Hobart Arc Welding News

Volume VII, No. 2, "Hobart Arc Welding News," a 24-page booklet of interesting photographs and articles on welding from all over the country, is now available. Copies are mailed free of charge to anyone interested in arc welding.

Many of the articles feature time- and money-saving applications. To get your copy, write the Hobart Brothers Co., Troy, Ohio.

Airco Announces New Hard-Facing Catalog

A new hard-facing catalog has been announced by Air Reduction Sales Company, Division of Air Reduction Co., Inc.

The 20-page, illustrated catalog contains detailed information on the complete Airco line of hard-facing alloys. Description of product, typical uses, mechanical properties, chemical analyses and a brief outline of recommended procedures are included. These data are further supplemented by allied information such as a tabulation of recommended grinding wheels for dressing deposits of Airco hard-facing alloys.

For a free copy of this new catalog, write the Airco sales office nearest you, or Air Reduction Sales Co., Division of Air Reduction Co., Inc., 60 E. 42nd St., New York 17, N. Y.

Handbook on Radiography

Eldorado Mining & Refining (1944) Ltd., P. O. Box 379, Ottawa, Canada, has recently completed the compilation of an up-to-date manual on the use of radium and Cobalt 60 in industrial radiography. This manual provides an introduction to those interested in industrial radiography and valuable information concerning the use of penetrating radiations from naturally occurring and artificially produced radioactive materials. For those persons interested in exploring the field in greater detail, suggestions for further study have been included throughout the text and in a selected bibliography. Among the topics covered are Source of Radiation; Fundamentals of Radiography such as Density, Contrast, Latitude, Speed, Screens, Geometric Considerations, Equipment, Determination of Exposure Time, Applications and Interpretations; a section on Radioactive Isotopes and a Bibliography. This Handbook consists of 71 pages copiously illustrated. Available from Eldorado Mining & Refining, price $2.00.

Welding News

Many articles of interest on subjects of new fabrications, salvage and repair possibilities, safety tools and cold bent resistance welding tips are included in the third-quarter issue of the "Ampco Welding News."

Copies of this publication can be obtained (gratis) by writing Ampco Metal, Inc., 1745 S. 38th St., Milwaukee 46, Wis.

Procedure Handbook of Arc Welding Design and Practice, New 9th Edition

Revised and re-edited, new information and data added, including latest welding procedures, design data and techniques; recognized the world over as the authoritative source of information on arc-welding design and practice; over 1200 pages, 1300 photographs and drawings; size 6 x 9 in.; bound in semiflexible, gold embossed, simulated leather; price $2.00, postage prepaid, in the United States; $2.50 elsewhere.

In a new 9th Edition, the *Procedure Handbook of Arc-Welding Design and Practice*, published by The Lincoln Electric Co. of Cleveland, Ohio, has been completely reorganized and re-edited to bring all information up to date and include recent important welding developments. New design data has been included to make the Handbook more helpful to designers of welded machines and structures. Latest procedures are given for welding all metals and alloys commonly welded with manual open arc and hidden arc welding as well as automatic and semi-automatic hidden arc welding.

A completely new chapter on weldability has been written to present a comprehensive survey of this important subject. The latest information gathered from research projects and recent studies gives the facts which have changed welding procedures on many types of metals in the last few years.

The section on structural design has been enlarged and revised to include more information on welded rigid framing. Design techniques developed by leading consulting engineers for recently erected structures are included.

The machine design information in the Handbook has also been enlarged to include more information on the welded design of machine tools. This is in addition to the design data revised for other machinery of all classifications.

A completely new chapter has been added to the Handbook on welded design data. This chapter presents the fundamentals of welded design for both machinery and structures. It gives fundamentals, such as stress allowables, which can be applied to particular design problems. This chapter gives a designer the necessary tools for approaching any problem he may have in designing for welding.

The new 9th ed. contains over 1200 pages with more than 1300 illustrations in photographs and drawings.

This book may be purchased through the AMERICAN WELDING SOCIETY.

Welding for Defense Program

A program to furnish technical insight into Welding for Defense was launched recently by Eutectic Welding Alloys Corp. of New York with the publication of the first in a series of technical manuals designed to assist National Defense agencies and contractors in meeting the nation's industrial mobilization requirements.

The publications, titled "Eutectic National Defense Service Series," are being produced to provide broader understanding of important new developments in the welding science, with special emphasis on their applications to industrial mobilization for war, and on production and maintenance of war matériel. The first Manual of the series is titled "Welding Engineering and Design."

Other Manuals scheduled for early publication in the Eutectic National Defense Service Series include: "Jig and Fixture Design," "Tool and Die Salvage," and "Machine Repair, Maintenance and Salvage." Copies of the Manual may be obtained on request and without charge from the Technical Information Service, Eutectic Welding Alloys Corp., 40 Worth St., New York 13, N. Y.

Finishes for Aluminum

The 1950 edition of the process manual, "Finishes for Aluminum," has just been published by Reynolds Metals Co., according to D. P. Reynolds, Vice-President and Manager, General Sales Division, Louisville, Ky. These books are available without charge to engineers, chemists, production men and others when requested on company letterhead.

The new edition is a revision of the book first published in 1947. The 1950 edition not only supplies basic information on the various processes for applying surface finishes to aluminum, but also details the characteristics of the finishes so produced.

It includes information on 10 cleaning treatments including one for resistance welding, 15 mechanical finishes, 16 chemically produced finishes, 11 electrolytic oxide finishes, organic finishes and specialized finishes such as luminous paints and vitreous enamels. A section is also included on controls and tests.

Included for the first time is a guide for approximating typical costs of applying 20 different treatments to aluminum. Another new table gives typical finishing practices for a wide variety of aluminum products to serve as a suggestion when selecting a finish.

The new 124-page, 6 x 9-in. book con-

In all the world there's only one TUBE-TURN *Welding Fitting as shown by this trade mark... the right mark for* every *need in welding fittings and flanges.*

TUBE-TURN

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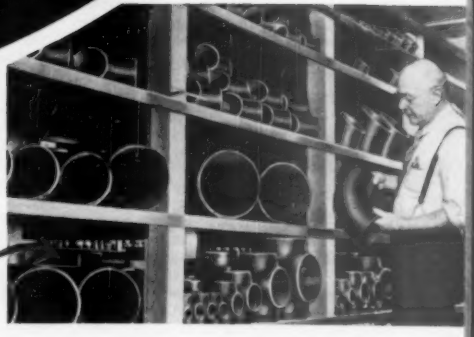

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tains 37 illustrations, 18 tables, a table of contents and an itemized cross index. It is wire bound to lie flat when opened. Also it carries a color-identifying tab on the backbone and across the page edges at the top of the book. This facilitates identifying the book either on a bookshelf or in a briefcase.

Modern Arc-Welding Lessons A.C. and D.C.

Modern Arc Welding Lessons A.C. and D.C. is a 192-page textbook published by Hobart Trade School, Inc., Troy, Ohio. Flexible blue fabricoid cover. $1.00 per copy with special prices to schools.

This book comprises the second part of the new five-part Hobart handbook, *Electric Arc Welding—Procedure and Practice*, and contains the complete series of 40 arc-welding lessons offered at the Hobart Trade School. Chapter headings include: Preliminary Instructions, Starting and Manipulating the Arc, Welding Common Joints with Bare Electrodes, Welding Light Gage Sheets with Coated Electrodes, General Welding with Coated Electrodes in the Flat, Horizontal, Vertical and Overhead Positions, Pipe Welding, Welding Cast Iron and Special Practices and Tests.

The text material, following the introduction and preliminary instructions, is divided into welding exercises of gradually increasing difficulty. The student is taken through the various problems involved in practical arc welding as rapidly as he can master the principles involved.

A book written in "easy to understand" words, giving all the fundamentals of arc welding, with descriptive pictures, charts and diagrams.

Airco Announces New Aircomatic Reprint

A new reprint, "The Aircomatic ® Welding Process," has been announced by Air Reduction Sales Co., a Division of Air Reduction Co., Inc.

This 26-page article, which originally appeared in THE WELDING JOURNAL, was written by A. Muller, G. J. Gibson and E. H. Roper and discusses the fundamentals of metal-arc transfer in inert-gas-shielded arc welding. Methods of overcoming porosity in aluminum welding by automatic and manual welding as well as stainless steel, heat-resisting alloys, clad materials and aluminum bronze are covered. Half of the paper is devoted to specific applications.

The article is illustrated with 68 photographs and charts. The text is further supplemented with 14 tables of test and specification data.

Copies of this reprint (ADR 66) may be obtained without charge by communicating with your nearest Airco sales office or writing Air Reduction, 60 E. 42nd St., New York 17, N. Y.

Heat Treatment and Properties of Iron and Steel

"Heat Treatment and Properties of Iron and Steel," a new circular just released by the National Bureau of Standards, presents basic theoretical and practical principles involved in the heat treatment of ferrous metals. This circular, which is now available from the Government Printing Office, has been prepared in simplified form principally to give an understanding of heat treatment to those unacquainted with the subject.

The effects of various treatments on the structural and mechanical properties of iron and steel are thoroughly discussed although many theoretical aspects and technical details have been omitted for the sake of simplicity. Subjects presented include properties of iron, alloys of iron and carbon, decomposition of austenite, heat treatment of steels, hardenability, heat treatment of cast iron, nomenclature of steels, recommended heat treatments, and properties and uses of steels. A list of selected references is also given, and a large number of graphs, tables and photographs illustrate the text.

Circular 495, "Heat Treatment and Properties of Iron and Steel," by Samuel J. Rosenberg and Thomas G. Digges, 33 pages, 25 cents a copy, is available from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Remittances from foreign countries should be in United States exchange and should include an additional sum of one-third the publication price to cover mailing costs.

Silver Brazing Bulletin

Handy & Harman, 82 Fulton St., New York 7, N. Y., has just released a new bulletin covering silver alloy brazing with Easy-Flo and Sil-Fos. It is a storehouse of facts and data. Tells where and how to use these alloys to the best advantage. Shows many interesting applications, describes fast brazing techniques. Tells how you can speed up production and save time. Write for a free copy to the above address.

These men are working for you

C. B. McLAUGHLIN, active, fast-thinking Manager of Tube Turns' Engineering Service Division, checks important design point on new application idea.

Enthusiastic, enterprising G. A. GAUM, Sales Engineer, winds up extensive field trip with information that may save Tube Turns' customers time and money.

D. R. CHEYNEY, alert, ingenious Sales Engineer, visits a Tube Turns' customer with recommendations on alloy fittings designed to whip corrosion problem.

Conscientious, analytical J. D. TOLLIVER, Sales Engineer, goes into the field for performance data that can result in important contribution to piping technology.

IMPORTANT link between Tube Turns, Inc. and its customers is the group of skilled, experienced engineers who staff its Engineering Service Division. Their job: to expand piping technology through studies of piping performance and problems in the field; to enlarge the scope and utility of Tube-Turn welding fittings and flanges.

Today, the men of Engineering Service are making allies of alloys, solving major piping puzzles, extending the advantages of welding fittings and flanges to non-piping fields. Examples: development of the first aluminum flanges, making possible all-welded, all-aluminum piping systems; design of lighter, stronger truck axles fabricated with Tube-Turn welding fittings.

Ideas are their stock-in-trade . . . ideas focused on one basic objective: *new and better ways for welding fittings and flanges to serve you better.*

Write for free booklet on "TUBE-TURN Aluminum Welding Fittings and Flanges."

"Be Sure You See The Double tt"

TUBE TURNS, INC.

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NEW PRODUCTS

Cable Splicers

A new line of low-cost cable splicers known as "Lug-Set" splicers has recently been introduced by the Tweco Products Co. of Wichita, Kan. The new splicers are made in four sizes to handle cables from No. 6 through No. 4/0. Made of electrolytic seamless pure copper tubing, these splicers are easy to install in shops or on field jobs with the Tweco "Lug-Set" Block and Punch.

After the splicers are installed they can be covered with split rubber tubes that are also available from Tweco, and then covered with friction tape. These sleeves insulate the splicer and protect the splice from abrasive wear.

Top view of splicer attached

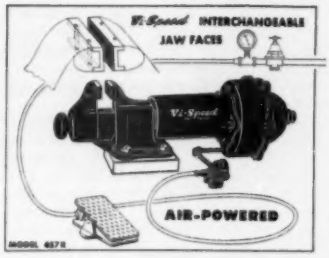
Bottom view of splicer attached

Tweco "Lug-Set" splicers make it easy and inexpensive to splice broken, cut or worn places in welding cables. Reel ends and short lengths can be quickly made into usable lengths. The splice will withstand tremendous pull and being made of pure copper they provide ample current-carrying capacity in all four sizes.

Complete information and literature on Tweco "Lug-Set" splicers, "Lug-Set" Block and Punch attaching tools, and other Tweco products is available by writing to Tweco Products Co., P. O. Box 666, Wichita, Kan.

Vise With Interchangeable Jaw Faces

These models, while having all the features and specifications of the popular Vi-Speed Standard Models 457 and 457-6, have something additional to offer—interchangeable jaw faces, as shown in the accompanying illustration.



The faces are hardened tool steel with either serrated or smooth surfaces, whichever convenience demands. They are firmly attached to the jaw castings by spring tempered pins driven into holes drilled in a manner to bind both faces and pins. They are quickly and easily removed by driving out the pins with a punch, after which other faces can be rigidly installed.

Vi-Speeds with Interchangeable Jaw Faces are especially valuable where heat is applied to the work near the vise. Continual exposure of ordinary vise jaws to high temperatures will gradually remove their hardness, but should this occur with either Model 457R or 457R-6 it is an easy matter to remove the jaws and have them rehardened or, after long use, to install new ones.

Manufactured by Van Products Co., Erie, Pa.

Welding Studs

New and improved arc-welding studs with arc shields for stud welding applications are manufactured by KSM Products, Inc., 6512 Park Ave., Merchantville 8, N. J. In addition, all stud welding equipment as well as replacement parts are available for immediate shipment.

The studs manufactured are fluxed by a new process which controls the quantity of flux in each stud to a plus or minus 1%.

The KSM standard design threaded stud is made by the thread rolling method. Thread rolling produces a stud approximately 20% stronger than comparable cut threads. The weldability of the KSM stud has been one of the motivating factors in an increasing number of firms incorporating KSM studs into their stud welding program.

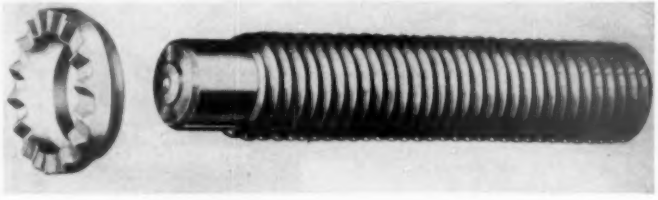
New Torch Design

Functional design and aluminum construction mark the most sensational gasoline torch improvements in 75 years, according to a report from Otto Bernz Co., Rochester, N. Y., manufacturers of torches, firepots and plumbers' tools. New features make torches lighter, more efficient, easier to handle and safer.

Basic style change is in stronger, flared tank design, resulting in greater fuel capacity, and weight balance at any fuel level, as well as better appearance. Bakelite pistol-grip handle is designed for easier handling, better balance and more efficient use.

Simplified pump construction reduces number of parts from 16 to 8, mimizing mechanical troubles and repair costs. Easier to insert, pump is perfectly sealed with finger-tight closing. More efficient check valve makes pumping twice easier and faster than formerly, and eliminates need for lockdown after pumping.

New safety feature is exclusive lock ring on needle valve. Valve cannot screw out nor be forced out by pressure, preventing flame from shooting out back of torch.

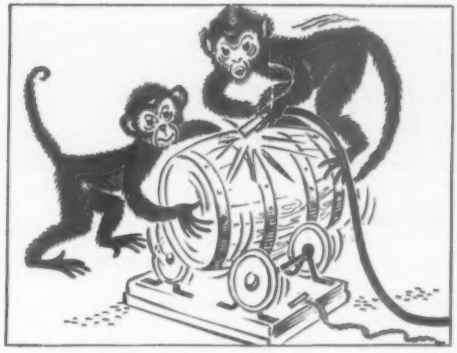


You're Smart Like a Fox...

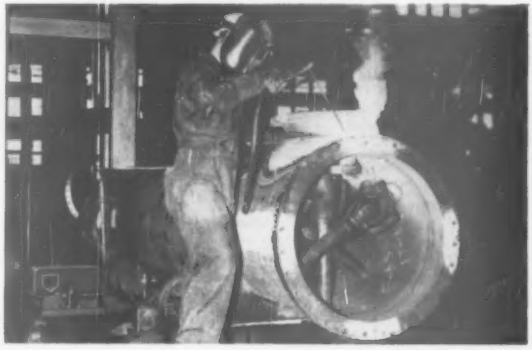
when you increase arc-time per hour with Worthington-Ransome Welding Positioners and Turning Rolls.

Not this... Spare your welders the chore of having to *climb* all over the work piece. Climbing, turning, propping time is *waste* time.

But this With a Worthington-Ransome Welding Positioner continually bringing work into position for convenient down-hand welding, your welders spend less time handling, more time welding.



Not this... Why do it the hard way when you can get it done the easy way?

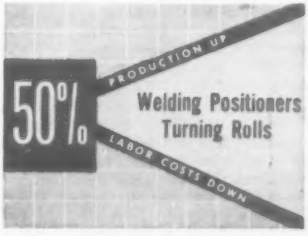


But this Manual or automatic welding really pays off when you use Worthington-Ransome Turning Rolls to rotate the work. This way, output goes up as much as 50% on either repetitive or job work.

Welding Positioner capacities from 100 lb to 20 tons. Turning Rolls from 3 to 150 tons, stationary and self-propelled.

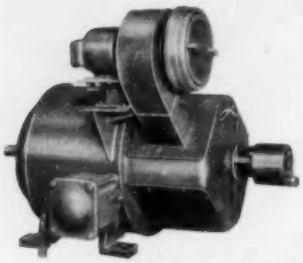
Write for Positioner or Turning Roll Bulletin, Worthington Pump and Machinery Corporation, Welding and Assembly Positioning Equipment Division, Dunellen, N. J.

WORTHINGTON



Special Filter for Blower-Cooled, Electronically Controlled Motor

Developed by Air Filter Corp. is a specially designed Airsan air filter for a Louis Allis blower-cooled, electronically controlled d.-c. motor. The Airsan air filter traps all atmospheric and processed dust, thus assuring a clean motor and minimizing motor maintenance. It extends commutator and brush life.



Courtesy of Louis Allis Co.

Further information on this and other applications of Airsan air filters can be obtained by writing Air Filter Corp., 108 N. Water St., Dept. 110, Milwaukee 2, Wis.

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New Packaging and Improved Design of WELDPOWER* CONTROL UNITS

New, compact enclosures, attractively finished in bronze and brown, save valuable bench space. Readily accessible operating controls allow rapid change-over from one job to another. Long famous for speed and accuracy in welding metals of high thermal conductivity, the new Raytheon stored energy Weldpower offers the maximum in ease of installation and operation.

NEW MODEL G WELDPOWER HEAD

Completely new, patented, compact design insures fast, inertia-free operation. Can be pre-set for accurate, consistent electrode pressure. Widely adaptable to precision welding light gauge metals, wire and small parts.

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Model 60 Capacity: 63 watt-seconds

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RAYTHEON *Excellence in Electronics*

RAYTHEON MANUFACTURING COMPANY
WALTHAM 54, MASSACHUSETTS

abstracts of CURRENT WELDING PATENTS

Prepared by V. L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington 10, D. C.

2,519,614—Welding Gun—Arthur T. Van Eck, Grand Rapids, Mich.

This patent covers a bar-welding tool which has a pair of supporting arms of current-conducting material with hinge means of the same material connecting the arms for angular movement in a plane. An electrode is carried by each of the supporting arms and force-applying means for articulating the arms is provided.

2,519,784 — Welding Transformer — William J. Oesterlein, Wauwatosa, Wis., assignor to Harnischfeger Corp., Milwaukee, Wis., a corporation of Wisconsin.

The patented transformer has a variable output and includes a pair of spaced magnetic stationary field members each of which has a notch on the inner face thereof. A stationary winding is received in the notches and has an open center. A movable magnetic core is positioned in the open center of the stationary winding and it has notches thereon for receiving a movable winding which is fixed thereto with relation to the said core notches. Means are provided for adjustably moving the core and its associated movable winding.

2,519,871—Motorized Torch Holder—John H. W. Bergerow, Wood-Ridge, N. J., assignor to Air Reduction Co., Inc., New York, N. Y., a corporation of New York.

This motorized torch holder is provided with special means adapted to raise and lower a torch with reference to a workpiece. The apparatus is controlled by a motor shaft which is driven in opposite directions for raising or lowering the bracket which positions the torch.

2,519,877 — Electrode Holder — Lawrence H. Bevard, St. Louis, Mo.

Bevard's electrode holder has a pair of electrode clamping jaws, a handle remote from the jaws, and a cam element for spreading the jaws extending lengthwise of the jaws and positioned wholly between the jaws and engaging the faces thereof at points spaced apart longitudinally of the jaws. An operating lever is provided and connects to the cam element.

2,519,939—Cutting Torch—Elmer H. Smith, Minneapolis, Minn., assignor to Smith Welding Equipment Corp., Minneapolis, Minn., a corporation of Minnesota.

Smith's patent relates to a torch head which has a plurality of special passages provided therein and special compressible sealing elements are provided in association with the tip of the torch.

2,520,001—Cutting Torch Tip—Clyde M. Eicher, Swissvale, Pa., assignor of

one-third to Sebastian C. Pugliese, Pittsburgh, Pa. and two thirds to Universal Tip & Equipment Co., a corporation of Pennsylvania.

In this novel cutting torch, the head has ports therein for the passage of cutting oxygen, preheat oxygen and combustible gas. The patent covers a special connection between a removable tip attached to the head and its relationship to the head for receipt of gases therefrom.

2,520,112—Arc Welding Electrode—Philip Bourque and Matt Kiilunen, Detroit, Mich.

This patented electrode comprises an elongated hollow body which has a plurality of welding electrodes positioned about the body in longitudinal alignment therewith. Means are provided for electrically connecting one end of the electrodes to the elongated hollow body.

2,520,151—Adjustable-Electrode Arc-Welding Torch—George G. Landis, South Euclid, and Norman J. Hoenie, Cleveland Heights, Ohio, assignors to The Lincoln Electric Co., Cleveland, Ohio, a corporation of Ohio.

A portable arc-welding tool is covered in the patent and includes a handle formed with a pair of spaced adjacent bores with an elongated member rotatably fitted in each of the bores and extending from one end of the handle in spaced but adjacent relation. Electrode gripping means are provided in the outer ends of such members and two intermeshing gears are fixedly mounted one on each of the members so that the members may be rotated in unison.

2,520,206—Silver Brazing Flux—Walter Goerg, North Bergen, N. J., assignor to Air Reduction Co., Inc., a corporation of New York.

This silver-brazing flux consists of approximately equal quantities of boric acid, potassium bifluoride and potassium tetraborate. A small amount of sodium alginate and sodium hexametaphosphate are also present in the flux as is an appreciable amount of water.

2,520,806—Welding Electrode—Theodore E. Kihlgren, New Providence Township, Union County, and George R. Pease and Pierre E. Le Grand, Plainfield, N. J., assignors to the International Nickel Co., Inc., New York, N. Y., a corporation of Delaware.

This patent covers a welding electrode having a core wire of nickel-copper alloy with the electrode being characterized by its adaptation for forming weld deposits of a high degree of ductility by a d.-c. arc-welding operation. A special flux coating is provided on the electrode.

2,520,926—Power Supply for Welding Apparatus—Harold J. Graham, Boston, Mass., assignor, by mesne assignments, to Graham Mfg. Corp., Detroit, Mich., a corporation of Michigan.

Graham's patent covers a generating and control system for supplying a current surge of initially high value and includes a generator having a field coil and an armature, which armature supplies the load current. An energy storing capacitor is charged from a direct-current power supply, and a normally open switch is connected in series with the capacitor and the field coil. Thus closing the switch discharges the capacitor through the field coil to result in a current surge of initially high value from the armature.

2,521,199—Method of and Apparatus for High-Speed, High-Pressure Oxygen Cutting of Metals—Roger S. Babcock, Plainfield, N. J., assignor to The Linde Air Products Co., a corporation of Ohio.

Babcock's cutting method comprises directing a jet of oxygen progressively against the surface of the body by a special type of a nozzle. Gaseous oxygen is supplied to the nozzle at normal ambient temperature and a pressure of between 450 and 600 psi. gage. The nozzle is adapted to increase the velocity of flow of the oxygen to values substantially above that of sound.

2,521,471—Welding Device—Thomas Lestler May, New York, N. Y., assignor to Hi-Ampere Tools Corp., Bronx, N. Y. a corporation of New York.

This welding device includes a pair of electrodes and means are provided for moving one electrode toward the other to grip a workpiece therebetween. Means are associated with the second electrode to move it from a normal position and other means connected to this electrode resist such movement. A switch is also connected to the second electrode and adapted to be closed after the second electrode has been moved from its normal position.

2,521,669—Torch Beveling Apparatus—John H. Rountree, Plainfield, N. J., assignor to The Linde Air Products Co., a corporation of Ohio.

Roundtree's apparatus is for plate edge preparation and includes an elongate frame member with a socket on the main frame for supporting a nose cutting nozzle adapted to cut a kerf in the plate to form a nose thereon. This frame member extends longitudinally of the kerf and terminates in a transversely extending guide longitudinally spaced from the nose cutting nozzle socket. A supporting arm is provided and is slidable transversely with respect to the kerf and a beveled cutting nozzle is mounted on the supporting arm and is movable toward and away from the nose of the nozzle.

2,521,922—Welded Metal Reel—Paul H. Kurtz, Elmhurst, Ill., assignor to Western Electric Co., Inc., New York, N. Y., a corporation of New York.

This patent covers a metal reel of a special welded construction.

2,522,146—Contour Welding Machine—Edwin L. Tichenor, Clifton, and William Cremins, Montclair, N. J., assignors to Curtiss-Wright Corp., a corporation of Delaware.

This welding machine has a welding head mounted for longitudinal and transverse movement for depositing weld metal and means are provided for guiding the weld head. Such guiding means include a fixed cam member and a cam follower that has a variable radius and which is urged into frictional engagement with the edge of the cam member. The welding head is arranged to follow corresponding movements of the cam follower. Additional means are provided for rotating the cam follower whereby it moves bodily along the edge of the cam and causes corresponding movement of the welding head.

2,522,364—Arrangement in Manufacturing of Coated Welding Electrodes—Ernst W. Grana, Hammarbyhojden, Sweden, assignor to Allmanna Svenska Electriska Aktiebolaget Vasteras, Sweden, a corporation of Sweden.

This patent covers a welding electrode coating device wherein a core wire receiving sleeve is provided and an extruding die is provided for receiving the sleeve and depositing a coating mass around the periphery of the sleeve.

2,522,408—Cold Pressure Welding—Anthony Bagnold Sowter, Wembley, England, assignor to The General Electric Co., Limited, London, England.

This method relates to cold welding two nonferrous members at room temperature and comprises the initial step of scratch-brushing the surface portions of the members to clean same and arranging the members with the clean surfaces in face-to-face relation. A surface pressure is applied to contacting members substantially normal thereto, which pressure is controlled to produce a partial reduction in thickness of the members in a strip-like area thereof of at least 70%. This causes an indentation in an area of the members to permit the adjoining metal of the members to cold flow sufficiently to weld the members at an area corresponding to the strip-like area.

2,522,482—Electric Arc Welding—Zigmont Edward Olzak, Beaver Falls, Pa., assignor to The Babcock & Wilcox Tube Co., West Mayfield, Pa., a corporation of Pennsylvania.

Olzak's patent covers a method of inert-gas-shielded electric welding wherein an arc is maintained between an electrode and a metal workpiece and a stream of inert gas is directed about the arc to shield the latter and molten metal in the weld zone. The inert gas used has a relatively high density and a low arc supporting potential. Also, another stream of gas having a relatively lower density and a relatively higher arc supporting potential is directed closely around the first-mentioned gas stream.

2,523,237—Torch-Guiding Tool—Willie Richardson, New York, N. Y., assignor of one-half to Alfred Weisstein and Samuel Weisstein, New York, N. Y.

This patented torch-guiding tool includes a carrier having three surface-contacting supporting members positioned in triangular relationship and supported to move on a supporting surface in a plane closely adjacent to the supporting surface. These supporting members include two rollers and a fixed center-point member. A cutter-supporting post is provided and a flame cutter is adjustably positioned on the apparatus with relation to the fixed center-point member referred to.

SECTION ACTIVITIES

prepared by C. M. O'Leary

Anthony Wayne

On Friday, September 22nd the Anthony Wayne Section held its first meeting of the 1950–51 season.

The meeting was held at Ruckman and Hansen, Inc. There were actual demonstrations on powder cutting, cast-iron cutting, pipe welding and brazing of cast iron.

Walter Love, technical representative of Air Reduction Sales Co. of Chicago, demonstrated powder cutting and cast-iron cutting. George Laws, of Ruckman and Hansen, Inc., demonstrated the pipe welding. Virgil Beck of The Beck Welding Works demonstrated brazing of cast iron. Each gave a short talk on welding and cutting processes.

The meeting proved to be an instructional and educational program. Lunch was served by the Brudi catering service. Sixty members and guests were present.

Arizona

The September meeting of the Arizona Section was held in the Aluminum Room of the Hotel Westward Ho at 7:00 P.M. It was a dinner meeting with an attendance of approximately thirty members.

The meeting was presided over by Arthur Tesmer in the absence of the Section's Chairman, James Johnson. The Section's attention was called to the fact that its membership exceeds the potential setup by National Headquarters by over fifty per cent.

Announcement was made of the appointment of William Fischer, Welding Engineer of The Lincoln Electric Co., as the new Program Chairman, taking over the former duties of Hal Savage, Arizona Welding Equipment Co., who asked to be relieved due to pressure of business.

Several short and very interesting talks were given by members of the Section, namely, Charles Fogwell, George Hunt, J. August Rau, William Mills and James Stacy. An unusual sound film describing oxyacetylene welding and cutting was shown through the courtesy of the U. S. Bureau of Mines.

It was agreed by all present that the meeting was a most enjoyable one.

Chattanooga

A special meeting of the Executive Committee of the Chattanooga Section was held at the Hotel Patten at noon on Aug. 25, 1950, for the purpose of appointing certain officers and committees and to discuss meeting plans.

It was decided to continue last year's policy of appointing a program committee of eight to assist the Program Chairman, each committee member to be responsible for planning one meeting. It was also decided to include a "Coffee Hour" as a regular feature of this year's meetings. The "Coffee Hour" will follow dinner and will include a 15–20 min. movie of general interest.

The following officers were appointed: *Program Committee Chairman*—A. R. McLain; *Coffee Hour Program Chairman*—L. S. Chambless and *Member at Large* (to replace Claude E. Phillips)—R. B. Bayston.

The following members were appointed as program committee members to furnish programs for the meeting dates as listed:

Oct. 6—James Wm. O'Neal, Sr., Converse Bridge & Steel Co.
Nov. 3—F. C. Chapman, Combustion Engineering - Superheater, Inc.
Dec. 1—Clarence R. Miller, Welding Gas Products Co.
Jan. 5—William I. Reilly, Cavalier Corp.
Feb. 2—R. G. Wilson, National Cylinder Gas Co.
Mar. 2—H. E. Davis, Combustion Engineering-Superheater, Inc.
Apr. 6—Paul H. Stuff, Ross Meehan Foundries
May 4—Horace H. Peek, Jr., Lookout Boiler & Mfg. Co.

All meetings are planned to be held the first Friday of each month at the Maypole Restaurant.

Chicago

The following officers have been elected by the Chicago Section for the 1950–51 season: *Chairman*—E. P. Auler; *1st Vice-Chairman*—A. F. Chouinard; *2nd Vice-Chairman*—I. H. Carlson; *Secretary-Treasurer*—L. C. Monroe; *Chairman Membership Committee*—I. H. Carlson; *Chairman Program Committee*—A. F. Chouinard and *Technical Representative*—T. B. Jefferson.

Cincinnati

The following officers have been elected by the Cincinnati Section for the 1950–51 season: *Chairman*—William Highwood; *1st Vice-Chairman*—Edward L. Foote; *2nd Vice-Chairman*—J. R. Bergmann; *Secretary-Treasurer*—Robert F. Martin; *Chairman Membership Committee*—George Jacoby; *Chairman Program Committee*—Edward L. Foote and *Technical Representative*—Wm. A. Maddox.

Colorado

The regular monthly meeting was held on September 12th in the Festival Room of the Oxford Hotel, Denver. Dr. F. A. Rohrman, Executive Director, Experimental Station, University of Colorado, spoke on "The Atomic Bomb and Its Value." Dr. Rohrman is well qualified to speak on this subject due to his association with this program from the beginning. His talk was very interesting and well received by all present.

Dallas

The September meeting was held on the 13th in the Auditorium of the Lone Star Gas Co. Dinner was held in Brockles Cafe. Technical speaker was J. C. Holmberg, Metallurgist, Tulsa Testing Lab. His subject was "Testing—Some Methods and Reasons," and was illustrated with forty slides. Refreshments were served following the technical session.

Detroit

Plant Visit to the Ternstedt Division of General Motors Corp. on September 15th got off to a grand start with a luscious dinner which was served for the nominal fee of $1.00.

Detroit Section Plant Visit to Ternstedt Division, GMC. Front row, sitting left to right, Officials of Ternstedt Division: H. M. Rissman, Detroit Plant Mgr., J. Conlon, General Plant Mgr., Webb Lee, Director of Personnel. Back row, standing, left to right, Officers of Detroit Section: J. R. Stitt, Keith Sheren, E. B. Brown, R. H. Bennewitz and J. M. Johnston.

Group of Detroit Members and Guests at Plant Visit

Following dinner, Webb Lee, Director of Personnel, introduced H. M. Rissman, Detroit Plant Manager, who in turn introduced the various members to operating management. Jim Conlon, General Manager of the Ternstedt Division, then gave a very brief and interesting history of Ternsted's modest beginning dating back to 1917. Today Ternstedt is the largest manufacturer of automotive hardware in the world.

Following Mr. Conlon's talk, the membership was divided into groups of eight and guided through the Plant. Among the items of interest were: high-production multiple press operations; unusual welding applications; unique stamping and bending setups; unusual packaging and protective coating applications; elaborate materials handling equipment and, the application which probably attracted the most attention, electronic paint spraying. An outstanding observation by all attending was the orderliness, cleanliness and organization maintained in this large plant.

The hosts were most gracious and cooperative and it was felt that everyone attending came away with some new ideas.

Programs for coming meetings are as follows:

No. 10—"Koldweld Process"
Dec. 8—Nontechnical Night, Walter P. Reuther, President, UAW-CIO
Jan. 12—Composite Forgings, Inc., Bill Guse's Hunting Films
Feb. 9—Quiz the Experts

Eastern Illinois

The following officers and chairmen committees have been elected by the Eastern Illinois Section for 1950–51: *Chairman*—Morse B. Singer; *1st Vice-Chairmain*—William W. Alston: *2nd Vice-Chairman*—Paul Cummins; *Secretary*—Herbert F. Depke; *Treasurer*—Fred Cowles; *Chairman Membership Committee*—Wayne E. Linn and *Technical Representative*—Morse B. Singer.

Hartford

On Thursday, September 21st, the Hartford Section met for dinner and meeting at the University Club.

Speaker at the technical meeting was Sereno B. Gammell, News Commentator Radio Station WTHT, Hartford, Conn. Mr. Gammell spoke on current news events and our part in them.

Houston

The September meeting was held on the 14th at the Ben Milam Hotel, Banquet Room, Houston.

Technical speaker was J. C. Holmberg, Tulsa Testing Laboratory, whose subject was "Testing—Some Methods and Reasons." Mr. Holmberg discussed the importance of inspection and testing, not only covering the tests customarily prescribed, but also other tests which are used for specific purposes.

Lehigh Valley

Dr. G. E. Claussen, Metallurgist, Reid-Avery Co. Inc., Baltimore, Md., was the guest speaker at the first meeting of the 1950–51 season, which was held Monday, October 2nd, in the Hotel Bethlehem, Bethlehem, Pa. J. R. Fairhust, *Chairman*, presided at the meeting.

Dr. Claussen gave a very interesting talk on the E60 series electrodes, describing each type and their respective applications. He also gave an illustrated discussion on the difficulties encountered in the welding of various types of stainless steels, and the designing of electrodes to overcome these problems. Members and guests participated in a discussion period following Dr. Claussen's presentation.

A dinner meeting preceded the technical session, at which time C. L. Kreidler, Lehigh Structural Steel Co., gave an educational talk entitled, "Design of Simple Lifting Fixtures."

Michiana

The Michiana Section started off its 1950–51 season with a film, talk and discussion on "Design for Silvery Alloy Brazing" led by Roger J. Metzler, Development Engineer of Handy and Harman. Some 35 members and guests were present, and an active discussion following the talk gave evidence of the interest in the subject. The dinner meeting took place on September 21st at the Prairie Steak House, South Bend, Ind.

It was pointed out that six points must be kept in mind by the designer. Clearance must be kept low to prevent costly use of the alloy. The parts must be capable of being cleaned and fluxed. During the brazing process, the assembly must be capable of being supported so that no, or little, load is put on the joint. The alloy must be placed so that the heat can reach it and finally, the part must be capable of having the flux removed. Parts designed with adequate consideration for these points will have joints with excellent strength, economically made.

Milwaukee

The Milwaukee Section held its first meeting of the current year on Friday evening, September 22nd, at the Ambassador Hotel.

A short color film exploiting the grandeur of fishing and vacationing in Wisconsin was shown during the coffee talk period. The audible reaction of the audience indicated that the film was enjoyed by all, especially by the "Musky" fishing enthusiasts.

It was agreed by all present, after a short discussion, that the usual procedure of the past be deviated from in that one of the meetings during the year would be devoted to a topic of interest other than welding.

The technical discourse, "Metallurgy for Welders," was presented by Anton L. Schaeffler of the Allis-Chalmers Corp. His simplification of a highly technical subject was most interesting and enlightening to the practical welder. He discussed extensively the structural changes that occur in a multiple pass weld bead during cooling. The amount of weld metal deposited and its effect on the ductility of the weld bead was explained with the aid of the TTT curves. Mr. Schaeffler showed a number of slides of diagrams and

photomicrographs in explaining why the ductility of a weld bead having a few heavy passes is lower than a similar size bead made with a larger number of lighter passes.

Approximately 65 members and guests were present.

New Jersey

The regular monthly meeting of the New Jersey Section for September was held on the 19th at the Essex House, Newark. The usual dinner preceded the meeting.

G. O. Hoglund, Manager, Welding Section, Aluminum Company of America, was the technical speaker. His subject was "The Growing Use of Aluminum Through Improved Welding and Brazing Methods."

A film "The Tool for the Job" was shown through the courtesy of the Air Reduction Co. This was its first showing.

O. B. J. Fraser, President of the A.W.S., gave a short talk on membership.

As is the custom of the Section, an "after meeting snack" or social hour was held.

The annual picnic held by the New Jersey Section took place on Saturday, September 16th (at The Pines) in Metuchen, N. J. Over three hundred members and friends of the SOCIETY attended this picnic. Various contests and games were held, plus an ample supply of food and drinks.

Schedule of meetings for the remainder of the season is as follows:

Nov. 21—"Welding in the Job Shop," L. Gilbert, Editor, Industry and Welding

Dec. 19—"Developments in Arc Welding Equipment," J. P. Couglin, Westinghouse Electric Corp.

Nick Kiernan, Chairman and Jack Riley, Vice Chairman, New Jersey Section

Photos by George W. Nigh

Horseshoe Throwing Contest at New Jersey Section Picnic

Jan. 16, 1951—Joint Meeting of A.S.-M.E. & A.W.S., "Comparison Between Welding and Other Methods of Fabrication in the Aircraft Industry," F. Albrecht, Glenn L. Martin Aircraft Co.

Feb. 20—"Brazing of Metals," R. J. Metzler, Handy and Harman

March 20—Symposium on Nondestructive Testing by Magnaflux, Zyglo, X-Ray, Gamma Ray, Sonic Method and Mass Spectrometry

April 17—"Welding of Cast and Wrought Nickel and High Nickel Alloys," International Nickel Co.

May 15—To be announced

New York

The following is a program schedule for meetings of the New York Section for the remainder of the season:

Nov. 14—"Proper Preparation for Welding," Charles H. Jennings, Westinghouse Electric Corp.

Dec. 12—"Tooling for Automatic Arc Welding," Cecil C. Peck, President, Cecil C. Peck Co.

Jan. 9—"Inert-Gas-Shielded-Arc Welding," John W. Mortimer, The Whitlock Mfg. Co., S. A. Yaczko, The M. W. Kellogg Co.

Feb. 13—Joint Meeting with the Society of Naval Architects and Marine Engineers, "Welding High-Pressure, High-Temperature Steam Piping," Roger W. Clark, General Electric Co., A. W. Rankin, Turbine-Generator Eng. Div., General Electric Co.

March 13—"Cutting and Flame Processes," R. S. Babcock, The Linde Air Products Co.

April 10—"Shop Problems in Welding," E. Isgnen, R. G. LeTourneau, Inc.

May—Annual Social Meeting

Niagara Frontier

The September 28th dinner meeting was held at the Hotel Sheraton, Buffalo, N. Y. Dinner speaker was Lieutenant Russell Camp, USN, who gave an excellent talk on "The Meaning of and Need for Security."

Technical speaker was H. T. Herbst, Development Engineer, The Linde Air Products Co. Mr. Herbst presented an interesting presentation on "Inert-Gas-Shielded Metallic Arc Welding." There was an attendance of 110 at this meeting.

Northwest

The following is a schedule of the meetings of the Northwest Section:

Nov. 13—"Railroad Shop Welding," LaMotte Grover, Air Reduction Sales Co.

Dec. 15—Christmas Party

Jan. 8—"Design for Resistance Welding," W. R. Plummer, Progressive Welder Sales Co.

Feb. 12—"Weldesign for Improved Products," John Mikulak, American Car and Foundry Co.

March 12—"Organization for and Applications of Maintenance Welding," Lew Gilbert, Editor, *Industry and Welding*

April 9—"Inert-Gas-Shielded-Arc Welding," T. W. Eselgroth, The Linde Air Products Co.

May 14—"Design of Structural Steel," Frederick H. Dill, American Bridge Co.

Philadelphia

The Philadelphia Section opened the 1950–51 season with its first meeting on September 18th.

The fine attendance and interest exhibited at this meeting promises a busy and successful year.

The paper of the evening "Imagination—The Keynote to Submerged-Arc Welding" by Mr. Stringham, Process and Development Engineer, The Lincoln Electric Co., was most interesting and informative. He emphasized that the use of a little imagination and ingenuity in con-

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junction with the five basic factors in submerged-arc welding was very important for the success of any job. The five basic factors he set up were proper joint design, proper position of joint, cleanliness of joint, proper fixtures and equipment and proper flux handling. By use of slides he illustrated how these factors had been combined to accomplish various jobs successfully.

The questions and discussion emphasized the importance with which the members present consider the application of submerged-arc welding.

The usual refreshments provided as an aid to informal and friendly discussion were served.

The Panel Discussion on Friday, October 6th, based on "Radiography" was enthusiastically received. The discussion of radiography and its use, particularly the new field opened by the "Hot Radiography" technique, made the evening very interesting and worth while for all those present.

The program for the Panel Discussions is as follows:

Nov. 3—"Necessity for and Effect of Stabilizers in Stainless Steels," *Chairman*—R. D. Thomas, Jr., Arcos Corporation

Dec. 1—"Design and Proper Application of Spot Welding Equipment," *Chairman*—C. W. Middlestead

Jan. 5—To be announced

Feb. 2—"Allowances for and Control of Shrinkage Due to Welding"

March 2—"Prevention and Control of Cracking Due to Welding"

April 6—Open panel with experts available to answer questions in all fields of welding

The technical program of monthly meetings for the remainder of the season is as follows:

Nov. 20—"Welding Aircraft Gas Turbine Components," George Richardson, General Electric Co. Discussion Leader—Frank Gardiner, I.T.E. Circuit Breaker Co. Coffee Talk—"Offstreet Parking," R. A. Mitchell, City Traffic Engineer

Dec. 18—"Inert - Gas - Shielded - Arc Welding Symposium," A. J. Hopper, Welding Engineers, Inc., Walter Mehl, Heintz Manufacturing Co., M. W. Brewster, Westinghouse Electric Corp. Discussion Leader—R. S. Phair, Budd Co. Sound Color Movie—"Flying Fisherman," Courtesy Eastern Air Lines

Jan. 15—Joint Meeting Society Naval Architects and Marine Engineers, "Fabrication of High-Temperature, High-Pressure Steam Piping," L. C. McNutt, United Engineers and Constructors, Inc. Discussion Leader—Harry W. Pierce, New York Shipbuilding Corp.

Feb. 19—National Officers' Night, Questions and Answers Competition Interrogator—A. J. Raymo, Baldwin Locomotive Works

March 19—"Titanium Metal and Alloys Containing Titannium," Earl Larsen, P. R. Mallory and Co. Inc. Discussion Leader—Dr. E. M. Mahla, E. I. du Pont de Nemours and Co. Coffee Talk "Consumer Complaints," George Whittam, Manager, Customer Service Dept., Gimbel Bros.

April 16—"Factors in Processing Steel Which Affect Weldability." Coffee Talk—1951 Phillies

May 12—Social Night—Dinner and Dance; Chairman—R. A. A. Guenzel

The officers for the Philadelphia Section for 1950–51 are as follows: *Chairman*—O. C. Frederick; *1st Vice-Chairman*—K. W. Ostrom; *Secretary*—J. S. Douglass; *Treasurer*—E. R. McClung, Jr.; *Chairman Membership Committee*—C. W. Middlestead; *Chairman Program Committee*—K. W. Ostrom and *Technical Representative*—A. John Erlacher.

Pittsburgh

The September 20th dinner meeting of the Pittsburgh Section was held at the Jacktown Hotel, Jeannette, Pa. The meeting was given over to an escorted 2½ hour tour of The Elliott Co. The tour included inspection of Diesel Engine Turbo-Charges, Steam Turbines, Centrifugal Blowers, Jet Ejectors, etc. The Company provided skilled personnel to conduct, describe and explain the manufacturing facilities and work in progress. There was an attendance of 110 on this tour.

Puget Sound

The October dinner meeting of the Puget Sound Section was held on the 12th at the New Washington Hotel, Seattle, Wash. Speaker was Professor A. L. Miller of the University of Washington. His subject was "Design and Construction of Welded Steel Frame Buildings."

The following officers and committees have been elected by the Puget Sound Section for the fiscal year: *Chairman*—Alex D. Sweek; *Vice-Chairman*—Wm. Snyder; *Secretary-Treasurer*—C. R. Goetjen; *Executive Committee*—J. H. Tadlock, Roy Kamb, Harold Hovland and Jerry Martin; *Progam Committee*—Howard Long, Robert S. Miller and Myron D. Stepath; *Membership Committee*—Stan Miller, Robert Hermon and Lloyd R. Hayward; *Reception Committee*—G. Morgan McBride Jr., and Roy A. Kamb; *Publicity*—Al Patnik; *Codes and Standards*—Elmer E. Gunnette and *Technical*—Gilbert F. Schaller, L. M. Crawford.

Sagiaw Vallney

On Friday, September 15th the Saginaw Valley Section in conjunction with the Detroit Section made a plant visit to the Ternstedt Division of the General Motors Corp. Complete writeup is given under "Detroit" Section Activities.

Salt Lake City

A special meeting of the Executive Committee of this Section was held on August 21st to appoint committee chairmen and members. The following appointments were made.

Finance Committee: Al Drake, *Executive Member;* Leo Powell, *Chairman;* Lew Pope and Louis Lombardi.

Technical and Educational Committee: Leo Davis, *Executive Member;* Joe Roberts, *Chairman;* Darwin Christofferson; William Lapp and Frank Rust.

Publicity Committee: Leo Davis, *Executive Member;* J. Robert Lang, *Chairman;* Marvin Beckstead and Edwin Carlson.

Program and Entertainment Committee: Al Bowcutt, *Executive Member;* Charles Bartlett, *Chairman Technical Division;* Paul Ownby, *Chairman Entertainment Division;* Ray Potts; Gordon Christensen; Ed Brown and Don Rosenbaltt.

Membership Committee; Al Drake, *Executive Member;* D. S. Jenkins, *Chairman;* C. Roldo Call; Donald Newell; J. Graham Daniels; Shirely F. Jensen; Arthur Ray; Hudson Francom; Dale Worden; A. S. Bouck and Orson Davenport.

St. Louis

An inspection trip through the Granite City Steel Co. plant, Granite City, Ill., was made on September 15th.

Five hundred and twenty took part in this excellent inspection tour. Attendance was divided into groups of 35 each and conducted through the mill by two guides to each group. Operations were explained at the various points of interest.

Susquehanna Valley

The following is the program for the remainder of the 1950–51 season.

Business Meeting 6:15 P.M.
Dinner 6:45 P.M.
Hotel Berwick unless advised otherwise.
Coffee Talk 7:30 P.M.
Movies 7:45 P.M.
Technical Subject 8:15 P.M.

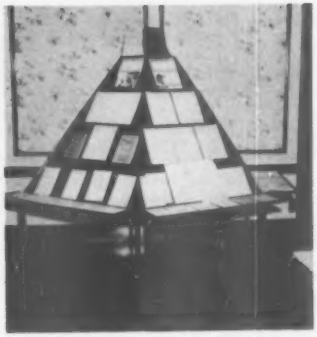
Dec. 6—"Resistance Welding," R. T. Gillette, Precision Welder & Machine Co.

Jan. 3—"Design for Silver Alloy Brazing," R. J. Metzler, Handy and Harman

Feb. 7—"Welding Aluminum Alloys" G. O. Hoglund, Aluminum Company of America

March 7—"Maintenance Welding," C. C. Keyser, Bethlehem Steel Co.

April 4—"Shielded Arc Welding," J. S. Douglass, The Linde Air Products Co.



All Welded A.W.S. Literature Display Fixture Used by Susquehanna Valley Section

May 2—Annual Meeting and Ladies Night

The October meeting was held on the 4th at the Hotel Berwick. Dinner speaker was Lewis Russell, Technical Representative of the Section. Mr. Russell discussed the literature available to the A.W.S. membership and supplemented his remarks with a complete display of the SOCIETY's publications, using an all-welded display fixture designed and constructed in his welding shop classes.

T. B. Jefferson, Editor of *The Welding Engineer*, was the technical speaker. Mr. Jefferson spoke around the theme, "Welding—Its Role in America's Future." He championed the cause of welding by comparing rivets to welds and pointing out the weaknesses in attitudes of old-time consultants who are too steeped in tradition and antiquated construction codes to wholeheartedly endorse welding. Mr. Jefferson concluded his remarks, that the future of welding really lies in education—educating the engineer and the public at large.

A technicolor, sound movie entitled "The Oxyacetylene Flame-Master of Metals," was shown.

A business meeting preceded the dinner at which time R. P. Schweyer was appointed Treasurer, succeeding R. C. Bellas, who resigned upon the transfer of his duties from Milton to Baltimore, Md.

The following are the officers of this Section for the fiscal year: *Chairman*—C. H. Folmsbee; *1st Vice-Chairman*—C. E. Reedy; *Secretary*—D. B. Howard; *Treasurer*—R. P. Schweyer; *Chairman Membership Committee*—W. C. Lamb; *Chairman Program Committee*—J. V. Carleton and *Technical Representative*—Lewis Russell.

Tri-State

The Tri-State Section met at Bockelman's New Harmony Way for a chicken dinner and a talk given by E. C. Hurt of Haynes-Stellite Division of the Union Carbide and Carbon Corp. Mr. Hurt presented a paper tracing the beginning of hard-surfacing applications and discussed some of the present hard-surfacing methods. This talk was illustrated by means of slides and was well received.

Mr. Werling, Membership Chairman for 1950–51, presented his plans for increasing the membership of this Section. These plans include a letter to each member stressing the value of the A.W.S. to him and asking for his cooperation in obtaining new members for the coming year. To stimulate the cooperation of the membership, plans were announced to offer prizes of $15.00, $7.50 and $5.00, respectively, to the three members who secure the most new members by Dec. 1, 1950.

Washington

The following is the schedule of meetings for the Washington Section for the remainder of the 1950–51 season.

Oct. 14—Plant Visit to the Bethlehem Steel Co., Steel, Sparrows Point, Md.

Nov. 28—Engineers Club—8:00 P.M., "Aircraft Aluminum Welding," and movie on "Pilotless Guided Vehicles," Fritz Albrecht, The Glenn L. Martin Co.

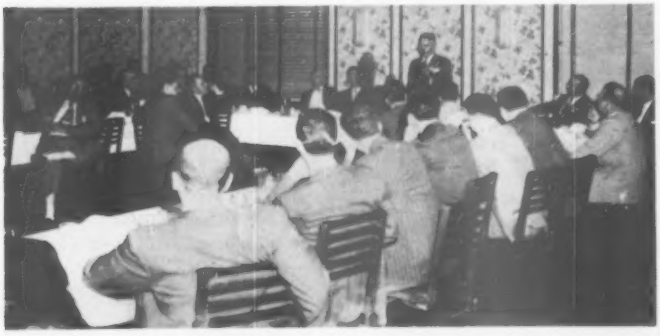
Dec. 19—Engineers Club—8:00 P.M., "Developments in Arc Welding Equipment," C. H. Jennings, Westinghouse Electric Corp.

Jan. 30—Engineers Club—8:00 P.M., "Welding of the S.S. *United States*," L. F. Bledsoe, Newport News Shipbuilding and D. D. Co.

Feb. 27—Engineers Club—8:00 P.M., "Building for the Nations," speaker to be selected by the U. S. Steel Corp.

March 27—Engineers Club—8:00 P.M., "Welding of Automobile Bodies," Jack Ogden, Fisher Body Division, General Motors Corp.

April 24—Fourteenth Anniversary Dinner, Address by H. W. Pierce, New York Shipbuilding Corp.



T. B. Jefferson Addressing October 4th Susquehanna Valley Meeting

Western Michigan

The first fall meeting of the Western Michigan Section was held on Monday evening, September 25th at the Elks Temple Cafeteria. The dinner was attended by 71 members and guests, and all enjoyed a very well prepared meal, cafeteria style.

The meeting was on Resistance Welding and was attended by about 80 members and guests. E. J. Del Vecchio of the Swift Electric Welder Co., Detroit, gave a very interesting lecture, along with a film on Resistance Welding supplied by Harvey Wheeler of the Arthur B. Sonneborn Co.

The merits of the speech were proved by the interest shown and many questions asked.

Wichita

Dinner meeting was held on September 11th at Geo. C. Christopher & Son Iron Works, Wichita, Kan.

The subject, "Welding Zinc Base Die Castings," was excellently presented by V. A. Henry of the Bendix Products Division, Bendix Aviation Corp.

Before the technical session a motion picture "Introduction to Die Casting" was shown through the courtesy of the New Jersey Zinc Co.

"What's New in Welding and Industry," was discussed by several members extemporaneously.

Worcester

The September 27th meeting of the Worcester Section was held at the Tower House, with 70 members and guests present. The dinner was preceded by the showing of a new color movie, entitled "Worcester, the Industrial Capital of New England," which was very well received.

Following the dinner, T. B. Jefferson, Editor of *The Welding Engineer*, presented a very interesting talk on "Welding—It's Role in America's Future." During his talk, Mr. Jefferson brought out what he calls the five "stumbling blocks" to be overcome before welding can find its true place in industry. These were the old problem of riveted vs. welded design; over-emphasis on locked-in stresses; the question of whether welding is a tool or a trade with the jurisdictional problems of labor that are involved; the unwillingness of older consulting engineers without a welding engineering background to accept welded design; the need of welding education in the schools and to the public at large.

Canadian Welding Society-Montreal Chapter

Monthly get-together meetings will be held on the third Monday of each month in the Marine Room of the Cafe St. Jacques, 415 St. Catherine St., East.

Toronto Chapter

Program of coming meetings is as follows:

Dec. 4—"Induction Brazing and Induction Heating," H. B. Osborn, Jr., Toco Division, Ohio Crankshaft Co.
Jan. 8—"Toronto Chapter Speakers Night"
Feb. 5—"Modern Uses of Arc Welding," Richard L. Sherwood, Hobart Brothers Co.
March 5—"Film Night"
April 2—"Resistance Welding Night" (Elections)
May 7—"New Developments in Welding," General Electric Co.

LIST OF NEW MEMBERS

September 1, to September 30, 1950

ARIZONA

Ames, Don (C)
Davenport, Clarence (C)
Germaine, Robert (C)
Herzog, George (C)
Phares, Robert (B)
Pieri, Ernie (C)

BIRMINGHAM

Horne, Charles T. (B)

CHICAGO

Bonds, S. S. (C)
Hupertz, Frank J. (C)
Mattson, Frank E. (C)
Privoznik, Louis J. (C)
Sheridan, Walter W. (C)

CINCINNATI

Jackson, Marc (B)

CLEVELAND

Benner, Robert (C)
Halloran, James C. (C)
Herrick, Clayton B. (C)
Meek, Frederick C. (C)
Sicherman, Harold L. (C)
Taylor, S. M. (C)
Vactor, Charles S. (C)
Wellendorf, Frederick (C)

COLORADO

Scott, F. C. (C)

COLUMBUS

Sopher, Raeman (B)
Williams, Arthur J. (B)

DAYTON

Rauch, L. C. (B)

DETROIT

Black, Harry B. (B)
Boyd, W. E. (C)
Morton, George D. (B)
Schouster, Earl J. (B)
Taylor, David A. (C)

HARTFORD

Anderson, Allan G. (B)
Bauer, Frank B. (B)
Crowley, Edmund J. (C)
Firestone, Gustave A. (B)
Kalber, William P. (B)
Lefebre, Alfred (C)
Ottavi, Victor (C)
Rusch, Richard (B)
St. Cyr, Joseph (B)
Welch, L. K. (C)
Whitney, Thomas A. (C)

HOUSTON

Blair, Willie E. (C)
Brandt, William T., Sr. (B)
DeZavala, L. K. (C)
Elam, Nolen E. (B)
Lewis, Walter T. (B)
Lindinger, Joe L. (B)
Meyers, G. W. (C)
Pattillo, S. M. (C)
Willbern, Roy (C)

INDIANA

Bussell, Fred S. (B)

LOS ANGELES

Elmer, David A. (C)
Hansson, M. (C)

MARYLAND

Smith, Ray D. (C)

MICHIANA

Birocci, Richard D. (C)
Gafke, Harry (C)
Lavengood, Thom. H. (C)
Weis, John C., Jr. (C)
Wishart, Walter W. (C)

MILWAUKEE

Jansen, Richard L. (B)
Keim, Lee J. (C)
Noebel, Carlton (C)
Schneller, Alfred R. (B)
Soika, Emil (C)

NEW JERSEY

Clinton, Edward J. (C)
Fodor, Joseph M. (C)
McElrath, Thomas, Jr. (C)
Perry, B. H. (B)
Yaczko, Stephen (C)

NEW YORK

Glickman, Bernard (B)

NIAGARA FRONTIER

Snow, R. K. (C)

NORTHERN NEW YORK

Heckman, Richard L. (C)
Wassell, Frank A. (C)

NORTHWEST

Collodora, Louis J. (B)
Ellig, Donald B. (C)
Hanvey, Fred W. (C)
Sage, Lauren, W. (C)

PASCAGOULA

Holder, Edward H. (C)

PHILADELPHIA

Hitchcock, R. B. (B)
McFall, Thomas (C)

PITTSBURGH

Kunkler, Lawrence W. (C)

ROCHESTER

Boss, Robert G. (C)
Pickering, Robert J. (C)

ST. LOUIS

Law, N. J. (C)

SAN FRANCISCO

Mack, Bernhard V., Jr. (B)

SUSQUEHANNA VALLEY

Reedy, Fred O. (B)

TOLEDO

Braithwaite, Robert J. (C)

WASHINGTON

Pellini, William S. (C)

WESTERN MICHIGAN

Aldrich, Robert H. (C)
Anderson, Edwin J. (B)
Fritz, D. B. (C)
Hedges, Clyde A. (B)
Hill, Gordon L. (C)
Plating, Jack (B)

WICHITA

Eades, J. D. (C)
Noonan, Charles F. (C)
Parsons, Earl G. (B)
Smith, Glenn E. (C)

WORCESTER

Doherty, Cornelius J. (C)

NOT IN SECTIONS

May, C. F. (C)
Phillips, Arthur V. (C)
Roberts, R. H. (C)

Members Reclassified

ANTHONY WAYNE

Cary, Carl G. (C to B)
Clark, Max (C to B)
Cushing, William M. (C to B)
Geiser, Jacob S. (C to B)

CHICAGO

Szymko, Chester T. (C to B)

CLEVELAND

Cowles, Walter C. (C to B)
Jarms, J. J. (C to B)

COLUMBUS

Green, Roberts (B to A)

DETROIT

Plummer, William R. (B to A)

HOUSTON

Reitz, Paul F. (C to B)

KANSAS CITY

Brown, Andrew A. (C to B)
Olson, Ralph A. (C to B)

LOS ANGELES

Stoddard, Kenneth J. (C to B)

NEW YORK

Grover, LaMotte (C to B)

PEORIA

Peters, E. Donald (C to B)

PHILADELPHIA

Hussey, Frank W. (C to B)

SAGINAW VALLEY

Thomas, Morris D. (C to B)

TULSA

Geppelt Elmo W. (C to B)

WELDING RESEARCH COUNCIL
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American Institute of Mining and Metallurgical Engineers, American Society of Civil Engineers
American Society of Mechanical Engineers, and Society of Naval Architects and Marine Engineers

Supplement to The Welding Journal, November, 1950

The Effect of Nitrogen on Brittle Behavior of Mild Steels

The effect of any one of the variables which affect the brittle behavior of mild steel plates such as nitrogen, for example, cannot be treated separately as each is interrelated with other variables

by G. H. Enzian and G. J. Salvaggio

Abstract

Investigation of the brittle behavior of mild steel plates has shown that the effect of nitrogen may not be as pronounced as previously indicated. Several steelmaking and processing variables exert considerable influence on this behavior, and these must be considered in evaluating the significance of variations in nitrogen content.

In steels with low Mn/C ratios, little or no change in brittle behavior was found with nitrogen variations within the range normally obtained by various open-hearth practices. Steels with higher Mn/C ratios exhibited, in general, somewhat better properties, but these were more susceptible to variation with change in nitrogen content.

Some interesting observations are made concerning comparisons of tests and criteria used to determine transition temperatures. A good correlation was found between ductility transition temperature and sensitivity to cold work.

INTRODUCTION

THE brittle behavior of normally ductile steels under certain conditions of testing or service has intrigued metallurgists for many years. Sixty years ago, Henry Marion Howe, in his classic text *The Metallurgy of Steel*, devoted a chapter to "The Treachery of Steel" in which he discussed inexplicable, brittle-type failures of steel in service. Two of the better known cases which he mentioned were the "Lividia" and the "Maginnis" cases of boiler plate failure, in which steel of satisfactory soundness and ductility, by all standard laboratory tests, mysteriously failed abruptly in service.

In recent years, the brittle behavior of mild steels has become a matter of public as well as technical concern as a result of a number of structural failures encountered in welded Liberty Ships during the past war. The frequency of these failures, and the catastrophic consequences of some of them, stimulated a tremendous amount of investigation and research which, in the past few years, has produced a large number of technical papers dealing with causes for brittle behavior, and with methods for evaluating the susceptibility of steels to embrittlement.

Some of the more recent papers on factors affecting brittle behavior of steel have placed considerable importance on the nitrogen content. Perhaps the strongest statement concerning this element in steel appeared in a discussion of papers on brittle fracture of mild steel plates.[1] It was stated rather broadly: "Since any steel with a high nitrogen content is very prone to brittle fracture this alone should be sufficient to condemn (Project) Steel C." Such a position on nitrogen should be supported by quantitative information as to how much nitrogen in the steel constitutes a "high nitrogen content." In addition, consideration should be given to other factors which may be equally as important as,

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Presented at the Thirty-first Annual Meeting A.W.S., Chicago, Ill., week of Oct. 22, 1950.

or which may influence, the effect of nitrogen on the properties of the steel.

As a result of considerable investigation of factors affecting the quality of commercial steels, Graham,[2] in 1932, reached the conclusion that nitrogen was probably the most influential element in steel affecting its "sensitivity," which was defined as "the characteristic reaction rate . . . toward brittleness or hardness." Subsequent work based on this concept provided considerable information on the effects of small amounts of nitrogen on the behavior of steel under conditions of cold working and aging.[3–5] In view of current interest in low temperature properties of plate steels, it was felt desirable to expand the scope of previous work to include study of the effect of nitrogen variations on the behavior of mild steels at low temperatures.

The present paper summarizes the results obtained on a number of commercial plate steel heats using several tests for determining susceptibility to brittle fracture. The steels were made with deliberate variations in open-hearth steelmaking practices to obtain a range of nitrogen contents which might be encountered in the commercial production of the grade by different producers. Most of the heats were made with a Mn/C ratio of approximately 2.0, and a few were made with higher manganese and lower carbon contents to obtain a Mn/C ratio of about 4.5 to 5.0.

EVALUATION OF BRITTLENESS

A large number of tests and criteria have been used by numerous investigators[6–14] in the evaluation of brittleness of mild steels. The majority of tests are similar in that notched specimens are fractured, either slowly or in impact, over a range of temperatures, and a temperature at which a transition from ductile to brittle behavior occurs is used to rate the merit of the steel. Considerable work has been carried out in this connection in an attempt to find a suitable small scale test which will satisfactorily predict performance under actual service conditions, but none has attained universal acceptance. Some of the more common tests used include the standard keyhole-notch Charpy impact, the V-notch Charpy impact, the Penn State slow bend[6–8] (Schnadt type specimen), the Lehigh slow bend[8–10] and various notched specimens pulled in tension.[11–15]

Attention has recently been called[8, 9] to the existence of two types of transition; these have been termed the "fracture" and the "ductility" transition temperature. The former is measured by noting whether the appearance of the fracture is predominantly fibrous (shear or ductile) or predominantly crystalline (cleavage or brittle) in nature. The "ductility" transition temperature occurs at a lower temperature and is characterized by a change from high to low energy absorption during fracture, or the disappearance of all evidence of plastic deformation before complete rupture occurs. Another way of viewing the difference between these two transitions is that the "fracture" transition temperature represents the maximum temperature at which a crack propagates in a brittle manner, and the "ductility" transition temperature is related to the initiation of the crack which ultimately causes fracture. The distinction between these two transitions becomes important especially when an attempt is made to correlate results of laboratory tests with service performance, or to show a relationship between the various tests.

Vanderbeck and Gensamer[16] have shown relationships between small scale tests and service performance of mild steel plates obtained from ships which had experience failures. Emphasis was placed on the importance of small amounts of ductility observed at the base of the notch, and on low energy levels associated with this behavior. Good correlation between low energy levels obtained in V-notch Charpy tests and service performance was shown. In addition, it was shown that the transition zone observed in the keyhole-notch Charpy test was truly a "ductility" transition zone since 100% cleavage fracture with no shear directly below the notch was noted when low energy was required to produce fracture. Similarly, in tests where lateral contraction is used as a criterion, it was pointed out that ductility transitions can be determined from measurements made directly below the notch.

Fracture transition temperatures determined from a visual examination of the fractured surface correlate well with several other measurements made in the various tests. For example, it has been shown[16] that transition temperatures determined from the V-notch Charpy test are probably a measurement of the fracture transition temperatures. In the case of the Penn State slow-bend test, transition temperatures based on the lateral

Table 1—Chemical Composition of Steels Tested

Code	*C*	*Mn*	*P*	*S*	*Si*	*Cu*	*Ni*	*Cr*	*Mo*	*N₂*	*Mn/C ratio*
05	0.22	0.55	0.020	0.030	0.09	0.06	0.04	0.07	0.01	0.005	2.50
51	0.22	0.50	0.016	0.026	0.09	0.06	0.03	0.02	0.01	0.006	2.27
86	0.21	0.46	0.017	0.024	0.09	0.03	0.03	0.02	0.01	0.008	2.19
18	0.22	0.49	0.018	0.026	0.10	0.04	0.04	0.03	0.01	0.008	2.22
30	0.23	0.49	0.012	0.030	0.10	0.05	0.04	0.02	0.01	0.008	2.13
13	0.26	0.48	0.017	0.027	0.09	0.06	0.04	0.02	0.01	0.009	1.85
15	0.21	0.49	0.018	0.028	0.08	0.04	0.03	0.02	0.01	0.011	2.33
10	0.21	0.47	0.018	0.034	0.08	0.04	0.03	0.03	0.01	0.011	2.24
02	0.20	0.90	0.020	0.034	0.03	0.08	0.04	0.03	0.01	0.005	4.50
87	0.16	0.84	0.015	0.034	0.08	0.05	0.03	0.02	0.01	0.006	5.25
00	0.21	0.99	0.025	0.029	0.04	0.06	0.03	0.02	0.01	0.009	4.70
97	0.15	0.78	0.018	0.024	0.05	0.06	0.04	0.02	0.01	0.010	5.20

contraction at the base of the drill hole, correlate well with those from fracture appearance.[16]

MATERIAL AND METHODS

The steels used in this investigation were semikilled mild steels in which the steelmaking practice was varied to produce different nitrogen contents. In addition, four of the steels were made with higher Mn/C ratios to determine the effect of this variable. The chemical composition of the steels is listed in Table 1 in the order of increasing nitrogen content and grouped into two ranges of Mn/C ratio (1.85 to 2.50 and 4.50 to 5.25). Test specimens were all taken from midway between the center and edge of $^5/_8$-in. plates rolled from the second cut of the middle ingot of each heat. The hot rolling finishing temperatures were between 1820° and 1860° F., with the exception of Steel 87 which finished at 1900° F.

Results of static tensile tests showed yield strengths between 31,500 and 36,250 psi., ultimate tensile strengths between 59,000 and 66,000 psi., elongations in 8 in. between 25.0 and 34.0% and reductions of area between 51.0 and 64.5%.

The susceptibility of the various steels to embrittlement by cold work and aging was determined from the work-brittleness test suggested by Graham and Work.[17] Briefly, this test consists of cold drawing a round bar, tapered from 0.450 to 0.475 in diameter, through a 0.450-in. die. The drawn bar, with cold work varying from 0 to about 10% reduction in area along its length, is notched at regular intervals and broken in an Izod machine.

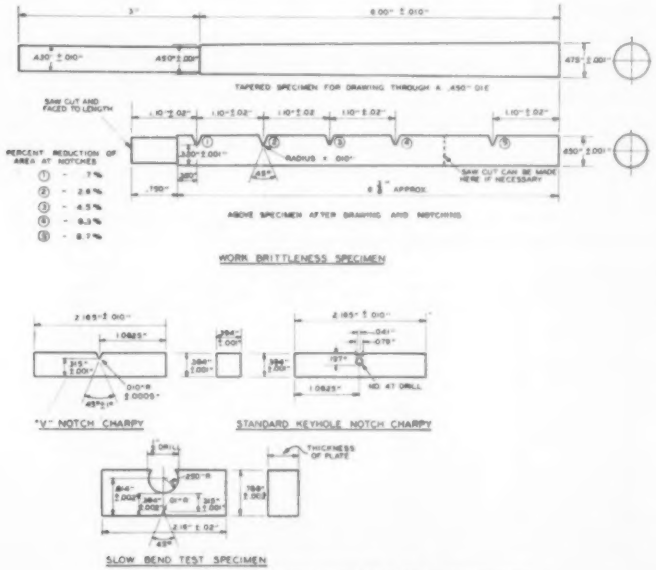
TAPERED SPECIMEN FOR DRAWING THROUGH A .450" DIE
SAW CUT AND FACED TO LENGTH
PERCENT REDUCTION OF AREA AT NOTCHES
ABOVE SPECIMEN AFTER DRAWING AND NOTCHING
WORK BRITTLENESS SPECIMEN
"V" NOTCH CHARPY
STANDARD KEYHOLE NOTCH CHARPY
SLOW BEND TEST SPECIMEN

Fig. 1 Test specimens used in this investigation

Fracture transition temperatures were determined from the V-notch Charpy test, and from lateral contraction measurements at the drill hole of the Penn State slow-bend test specimen.

Ductility transition temperatures were obtained from the keyhole Charpy test, low energy level (10 ft.-lb.) in the V-notch Charpy test, and the lateral contraction at the base of the notch in the Penn State slow-bend test.

The dimensions of the various test specimens used in this investigation are shown in Fig. 1.

TEST RESULTS

Typical results obtained from the different low-temperature tests are shown in Figs. 2 to 4. From curves such as these the fracture and ductility transition temperatures were determined using the following criteria:

(A) Charpy keyhole tests: A temperature at about the midpoint of the transition range was considered the ductility transition temperature.

(B) Charpy V-notch tests:
1. A temperature at about the midpoint of the transition range was considered the fracture transition temperature.
2. The temperature at which 10 ft.-lbs. were absorbed was taken as the ductility transition temperature.

(C) Penn State slow-bend tests:
1. The temperature at the center of the abrupt decrease in lateral contraction at the drill hole was regarded as the fracture transition temperature.
2. The temperature at which the lateral contraction at the base of the notch was equal to that at the drill hole at the fracture transition temperature was chosen as the ductility transition temperature.

A summary of the transition temperatures determined from the varitests is shown in Table 2. Also included in the table are the values for Project Steels A and C, taken from the report of Klier, Wagner, and Gensamer.[6] (The temperature for 10 ft.-lb. V-notch Charpy was determined from curves plotted for these steels; the other values were tabulated in the paper.)

The work-brittleness test was used to evaluate the effect of cold work and aging on the room temperature toughness of the steels. One group of specimens was broken immediately after being drawn and notched, while

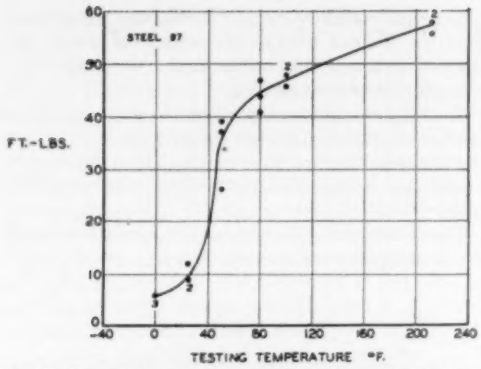

Fig. 2 Typical impact data obtained from the keyhole notch Charpy impact test—Steel 97

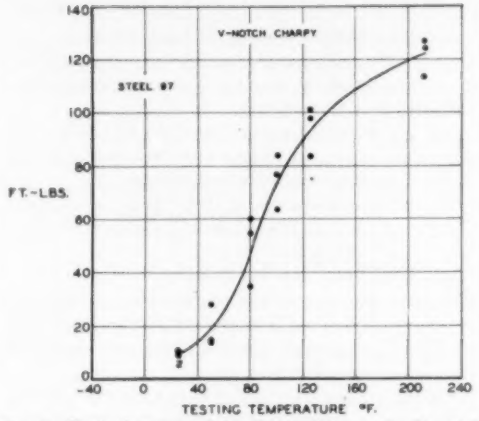

Fig. 3 Typical impact data obtained from the V-notch Charpy impact test—Steel 97

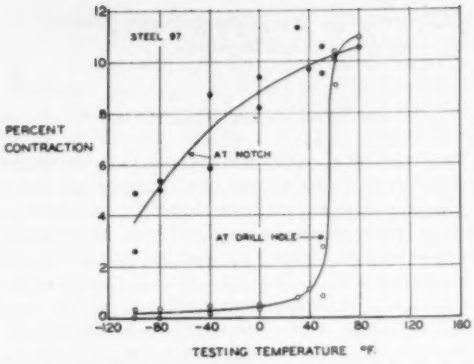

Fig. 4 Typical data obtained from the Penn State slow-bend test—Steel 97

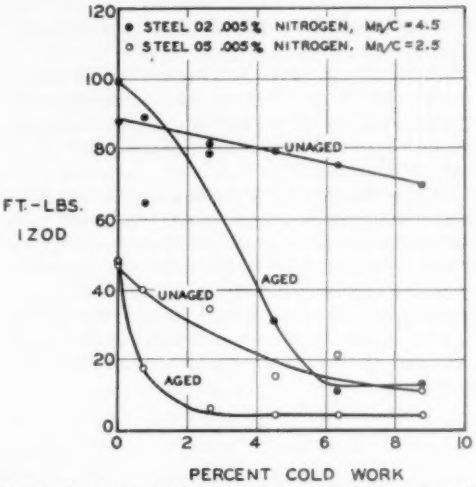

Fig. 5 Typical work-brittleness curves for two steels with similar nitrogen but with different Mn/C ratios

another group was aged for 1 hr. at 450° F. before testing. Some typical curves of the test results are shown in Fig. 5. In order to describe the strain-sensitivity more easily than by the use of separate curves for each steel, a quantitative index called the "E-index of embrittlement" was used. This index, which has been used in previous work,[5] is merely the sum of the Izod values obtained at each percentage of cold work, includ-

Table 2—Summary of Transition Temperatures

		Fracture transition, ° F.		*Ductility transition, ° F.*			
Steel	*Nitrogen, %*	*Charpy-V*	*Penn State drill hole*	*Charpy-V at 10 ft.-lb.*	*Charpy keyhole*	*Penn State base of notch*	*Mn/C ratio*
05	0.005	90	50	45	50	−50	2.50
51	0.006	95	80	50	45	−65	2.27
86	0.008	90	65	40	35	−55	2.19
18	0.008	90	70	45	50	−65	2.22
30	0.008	80	65	30	35	−60	2.13
13	0.009	110	75	45	60	−60	1.85
15	0.011	115	85	55	50	...	2.33
10	0.011	95	95	50	35	−60	2.24
02	0.005	55	25	−10	10	−80	4.50
87	0.006	45	30	10	15	−85	5.25
00	0.009	70	30	5	25	...	4.70
97	0.010	85	55	25	40	−75	5.20
Project,[6] Steel A	0.004	90	40	40	0	...	1.93
Project,[6] Steel C	0.009	100	95	40	15	...	2.00

ing the unstressed value, and is a relative measure of the area under the work-brittleness curve. Clearly, an insensitive steel will have a high index while a sensitive steel will have a low index. The E-index values for each of the steels are shown in Table 3.

Table 3—Work-Brittleness Test Results

Steel	*Nitrogen, %*	*Mn/C ratio*	*E-index of Embrittlement*	
			Unaged	*Aged*
05	0.005	2.50	286	96
51	0.006	2.27	151	134
86	0.008	2.19	180	99
18	0.008	2.22	171	91
30	0.008	2.13	128	91
13	0.009	1.85	119	75
15	0.011	2.33	172	87
10	0.011	2.24	152	102
02	0.005	4.50	363	132
87	0.006	5.25	342	170
00	0.009	4.70	483	301
97	0.010	5.20	456	322

DISCUSSION OF RESULTS

Transition temperatures obtained from the different low temperature tests are plotted against nitrogen content in Figs. 6 to 10. In those cases where the data were available, Project Steels A and C were plotted along with the points for the present investigation. The curves of fracture transition temperature vs. nitrogen (Figs. 6 and 7) show that this type of transition was affected by the nitrogen content. In general, an increase in nitrogen from 0.005 to 0.011% resulted in an increase in the fracture transition temperature. However, Figs. 8, 9 and 10 show that there was no significant

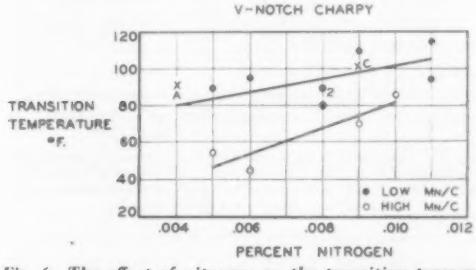

Fig. 6 The effect of nitrogen on the transition temperature as determined from the V-notch Charpy test

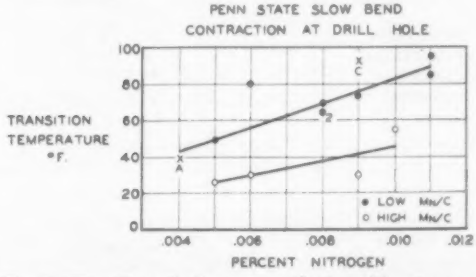

Fig. 7 The effect of nitrogen on the transition temperature as determined from the contraction at the drill hole in the Penn State slow-bend test

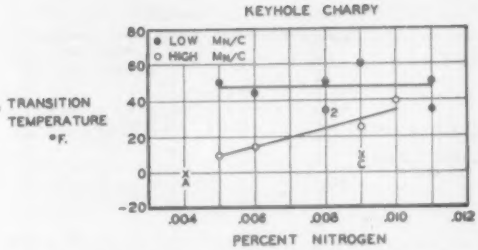

Fig. 8 The effect of nitrogen on the transition temperature as determined by the keyhole Charpy impact test

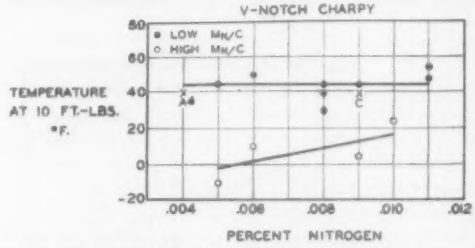

Fig. 9 The effect of nitrogen on the temperature at 10 ft.-lb. in the V-notch Charpy impact test

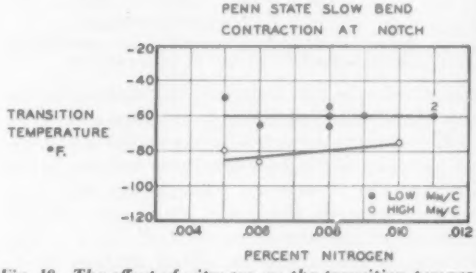

Fig. 10 The effect of nitrogen on the transition temperature as determined from the contraction at the base of the notch in the Penn State slow-bend test

change in ductility transition temperature in any of the tests with change in nitrogen in the steels with a Mn/C ratio between 1.85 and 2.5.

Attention is called to the location of the reported keyhole Charpy transition temperatures for Project Steels A and C in Fig. 8 in relation to the present tests. This was the only instance of marked disagreement between the Project Steels and the steels used in this investigation and was not noted until the test results were assembled. The authors are of the opinion that the apparent discrepancy in this case is related to the method of interpretation of the test results rather than to an actual difference in transition temperatures of the steels.

The steels with a higher Mn/C ratio (4.50–5.25) appear to behave differently from those with the lower Mn/C ratio. First, the general level of both the fracture and the ductility transition temperature was lower. Secondly, with a higher Mn/C ratio, the ductility transition temperature increased with increase in nitrogen

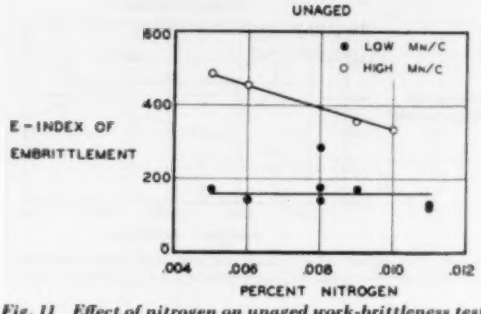

Fig. 11 Effect of nitrogen on unaged work-brittleness test results

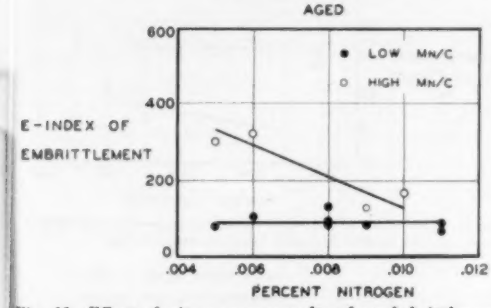

Fig. 12 Effect of nitrogen on results of work-brittleness tests aged for 1 hr. at 450° F. before testing

content, whereas this transition temperature for the lower Mn/C ratio steels was apparently not affected by variation in nitrogen content between 0.005 to 0.011%.

A summary of the work-brittleness test results are plotted in Figs. 11 and 12. Nitrogen had little or no effect on the steels with a low Mn/C ratio but was shown to be detrimental to the high Mn/C steels. However, in general, the steels with the high Mn/C ratio were less sensitive to cold work than those with low Mn/C ratio. Aging for 1 hr. at 450° F. increased the sensitivity of both groups, but the general relationships with regard to nitrogen variations remained essentially unchanged.

CORRELATION OF TESTS

An attempt was made to correlate the results obtained from the various tests used in this investigation, taking into consideration the criteria used in each case for evaluating brittle behavior. Although most of the transition temperatures (especially the ductility transition) fell within a fairly narrow range, the correlations obtained are good. In Figs. 13 to 16, the solid lines represent the relationships calculated by the method of least squares, while the dotted lines represent the standard deviation, σ, from the regression line.

Figure 13 shows the correlation between the fracture transition temperature determined by the V-notch Charpy and the Penn State slow-bend test. Most of the points fall reasonably well within a scatter band representing a spread in the Charpy V-notch transition temperature of roughly 15 to 35° F. higher than that determined by the slow-bend test.

The relation between ductility transition temperatures determined from the Penn State slow-bend test

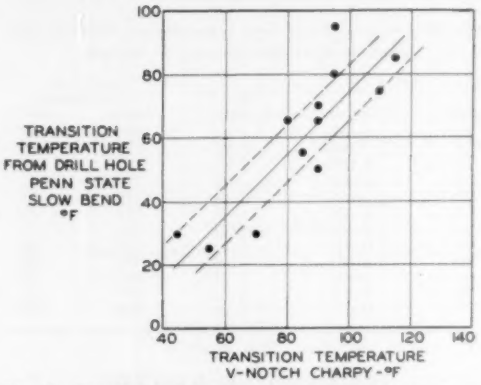

Fig. 13 Correlation between the transition temperature determined from the contraction at the drill hole in the Penn State slow-bend test and the transition temperature in the V-notch Charpy test

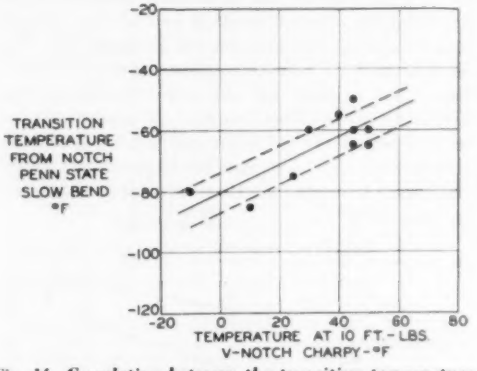

Fig. 14 Correlation between the transition temperature determined from the contraction at the base of the notch in the Penn State slow-bend test and the temperature at 10 ft.-lb. in the V-notch Charpy test

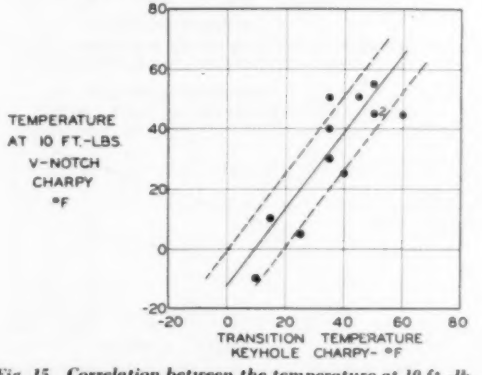

Fig. 15 Correlation between the temperature at 10 ft.-lb. in V-notch Charpy test and the transition temperature in the keyhole notch Charpy test

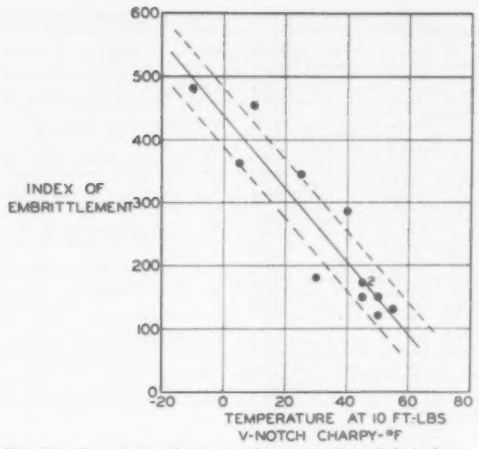

Fig. 16 Correlation between the unaged work-brittleness test results and the temperature at 10 ft.-lb. in the V-notch Charpy test

and for 10 ft.-lb. V-notch Charpy is shown in Fig. 14. These results show considerable variance between the transition temperatures obtained in the two tests, with the slow-bend test giving values that seem unreasonably low.

The relationship between the temperature for 10 ft.-lb. V-notch Charpy and the ductility transition temperature for keyhole Charpy specimens is shown in Fig. 15. The correlation seems quite good, but the temperatures determined from the keyhole test average a few degrees higher than those for the same steels in the V-notch test. These results are opposite from those found by Vanderbeck and Gensamer[14] by about the same order of magnitude. Their results indicate the V-notch temperature at 10 ft.-lb. to be slightly higher than the keyhole-notch ductility transition temperature. As previously mentioned in discussion of the keyhole Charpy test results, the authors believe that such discrepancies may be inherent to the lack of a precise reference point for determining the keyhole Charpy transition temperature.

The correlation shown in Fig. 16 between strain-sensitivity, as determined from work-brittleness tests in terms of the "E-index," and the temperature at 10 ft.-lb. V-Charpy is particularly interesting. Work-brittleness tests are considerably easier and less expensive to make than other tests which have been proposed to determine transition temperatures. The work-brittleness test has been used in laboratory investigations for a number of years, and it has been found that strain-sensitivity is a useful measure of quality in predicting the probable behavior of steel in fabrication and service, particularly under conditions involving cold working and/or strain-aging. The results of the present tests, showing direct correlation between strain-sensitivity and loss of ductility at low temperature, indicate that information already available on factors affecting strain-sensitivity should also be applicable to the problem of brittle fracture of ship plate steels. In addition, it would seem that the work-brittleness test provides a simple and inexpensive method for evaluating the relative susceptibility of ship plate steels to brittle fracture.

SUMMARY AND CONCLUSIONS

The results obtained in the present investigation indicate that variations in nitrogen content between 0.005 and 0.011% have little effect on the notch sensitivity of semikilled mild steels with a low Mn/C ratio (1.85–2.50) if certain criteria are used for evaluation. Criteria based on low-energy levels in the V-notch Charpy test, which correlate well with certain service conditions, or ductility transition temperatures in the keyhole notch Charpy and Penn State slow-bend test clearly show this.

Evaluation of notch sensitivity based on other criteria may lead to entirely different conclusions regarding the effect of nitrogen. For example, many tests performed on Navy Project Steels A and C,[6, 12, 15] which were similar in composition but contained different amounts of nitrogen, have shown dissimilar properties. It was concluded that these dissimilarities were caused primarily by the difference in nitrogen content. Data for these two steels taken from Klier, Wagner and Gensamer[6] have been plotted on some of the curves obtained from results of this investigation (Figs. 6 to 9). With the exception of transition temperatures determined from keyhole Charpy tests, the values for Project Steels A and C agree fairly well with those obtained in the present study. Results based on the contraction at the drill hole in the Penn State slow-bend test (Fig. 7), indicate that nitrogen is detrimental when notch toughness is evaluated in terms of fracture transition temperature. However, when ductility transition temperatures or low energy levels are used (Figs. 8, 9, 10) such an effect of nitrogen is not apparent.

In steels of higher Mn/C ratios (4.50–5.25), despite the fact that nitrogen does show an adverse effect on the brittle behavior, the general level of transition temperature (both fracture and ductility) remains below those steels with a Mn/C ratio of 1.85–2.50. This behavior has been supported mainly by Tipper, *et al.*,[18] while others[15,19] have shown that the Mn/C ratio had little or no effect. Although this investigation has included only two ranges of Mn/C ratios, the results indicate that this value is important and must be considered in establishing specifications for steel based on chemical composition.

On the basis of these test results, it seems evident that factors other than nitrogen may materially affect the apparent brittle behavior of mild steels, and that discrimination between steels of this type based on nitrogen content alone is not entirely justified.

ACKNOWLEDGMENT

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operation in carrying out this investigation, and the management of Jones & Laughlin Steel Corp. for permission to publish the results.

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Effect of Welding on the Properties of Titanium-Carbon Alloys

Inert-gas shielded tungsten arc process satisfactory for welding titanium carbon alloys. A carbon content of 0.25% represents maximum for ductile welds in the as-welded condition

by E. M. Mahla and R. B. Hitchcock

INTRODUCTION

WITH the rapid development of production facilities for ductile titanium, interest in this unusual metal and its alloys has reached into most fields of engineering endeavor. Because of its attractive strength/weight ratio, its intermediate-temperature properties and its corrosion resistance, interest has been particularly high in the aircraft industry, as well as in other parts of the transportation industry. The chemical industry is attracted by its excellent corrosion resistance.[1]

The common methods of preparation of titanium metal have been reported in detail[2,3] as have data pertaining to mechanical and physical properties and corrosion resistance.[4] Several papers on the welding of titanium have been published,[5–8] and it has been demonstrated that titanium is readily welded by the inert-gas shielded tungsten arc process and by the common methods of resistance welding. Some of the data published on welding indicates that a probable relationship exists between carbon content and weld ductility. The present work was undertaken to confirm the relationship and to determine tentative limits on carbon content to give ductile welds in the as-welded condition. Such information will be controlling on the method of melting, particularly for sheet stock, which must be readily welded for fabrication into much of the equipment for which the metal appears best suited.

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Presented at the Thirty-first Annual Meeting, A.W.S., Chicago, Ill., week of Oct. 22, 1950.

EXPERIMENTAL PROCEDURES

Materials

When this investigation was undertaken, samples of titanium sheet were at a premium and it was impossible to secure the complete range of carbon contents needed with other composition and processing variables held constant. Therefore, commercial titanium sheet was obtained from several sources to provide the range of carbon content herein reported, and as a result, the gage of the sheet varied over a relatively wide range. In many instances insufficient material was obtainable to carry out all the desired tests. The carbon and nitrogen analysis for these materials are given in Table 1, along with the sheet thickness.

Table 1—Carbon and Nitrogen Analysis and Sheet Thickness of Titanium Alloys Used

Carbon, %	*Nitrogen, %*	*Thickness, in.*
0.015	0.030	0.084
0.020	...	0.062
0.040	0.060	0.055
0.050	...	0.053
0.068	0.034	0.071
0.092	0.017	0.125
0.100	0.030	0.062
0.113	0.031	0.114
0.150	...	0.087
0.250	0.010	0.062
0.264	0.025	0.083
0.332	0.023	0.125
0.345	0.028	0.055
0.385	0.074	0.071
0.400	0.055	0.066
0.400	0.010	0.062
0.460	0.010	0.062
0.465	0.146	0.086
0.495	0.060	0.062
0.500	...	0.085
0.500	0.040	0.086
0.503	0.021	0.125
0.647	0.011	0.077
0.800	0.035	0.114
0.900	0.019	0.125
1.070	0.049	0.500 (welded with filler rod 0.780% C, 0.035% N)

Welding

The affinity of titanium for hydrogen, oxygen and nitrogen at temperatures above 880° C. (1616° F.) is high; sufficient contamination by these elements results in brittleness of the material. At the present time, the inert-gas shielded tungsten arc-welding process provides the best means for preventing exposure of the hot weld metal to the atmosphere during and after welding. This method was employed for these tests with argon as the inert gas and was apparently successful in providing adequate protection and avoiding serious contamination from the atmosphere. In order to avoid any complications from the addition of filler metal, all welds (except in the 0.500-in. material) were made by fusing abutting edges together. The samples were clamped tightly to a grooved $^1/_4$-in. thick copper plate with the weld seam directly over the shallow groove. Complete gas coverage of all weld metal was indicated by the bright, clean, shiny surfaces of the completed weld. For the most part, manual welds were made. In all cases direct-current straight polarity was used. Typical welding conditions are presented in Table 2. Weld seams varied in length from 2 to 10 in.

Table 2—Typical Welding Conditions for Titanium-Carbon Alloys

Thickness, in.	*Current,* amp.*	*Voltage*	*Tungsten, in.*	*Argon, c.f.h.*	*Speed of welding, in./min.*
0.055	115	16	$^3/_{32}$	16	12
0.062	125	14	$^3/_{32}$	22	8
0.071	120	16	$^1/_{16}$	18	12
0.077	125	15	$^3/_{32}$	22	8
0.083	135	14	$^3/_{32}$	18	12
0.114	140	14	$^3/_{32}$	20	10
0.125	195	16	$^3/_{32}$	15	10

* Direct-current straight polarity.

Three of the welds tested in this work were made in an argon-filled box employing a conventional inert-arc torch with argon flow in addition to the box atmosphere. These welds were made by the Development Division of The Linde Air Products Co.

Some welds were annealed for $^1/_2$ hr. at 1400°, 1800°, 1900° and 2000° F. in an argon atmosphere and water quenched, cooled in argon, or furnace-cooled to determine the effect of short-time heat treatment on bend ductility.

Test Procedure

Bend Test. Formability of sheet metal is of critical commercial importance, and suitable bend ductility is mandatory in order to obtain widespread use of any new metal. One laboratory bend test which can readily be reproduced for evaluation of bend ductility has been employed by several investigators. This test, a type of guided free bend developed by the Remington Arms Co.,[9] involves the use of small forming dies suitably incorporated in a jig. The jig is employed in the following manner: suitably prepared weld samples (all weld reinforcements removed, and all surfaces sanded smooth in the longitudinal direction) are placed with the weld seam across the open female die. The bend radius is determined by manually forcing the sample into the female die with the guided male die, upon which pins of different radii can be placed. The maximum bend of the die is 100–105°, at which time the mating members of the dies meet with the sample sandwiched between them and around the pin. If cracking of the sample is observed during bending, the angle through which it has bent is measured and the next larger pin is used on a duplicate sample. If a sample bends satisfactorily to the maximum of the jig with the smallest available pin (smallest radius), it is manually bent to failure or flattened to 180°. The smaller the bend radius which a sample withstands, the more ductile the material. The term bend radius is used to denote the ratio of sample thickness to pin radius and is given the nomenclature 1.5T, 3.0T, etc. A 1.5T bend radius for material 0.062 in. thick (approx. $^1/_{16}$ in.) means that sample bent to the maximum of the jig employing a pin whose radius is $^3/_{32}$ in.

Tensile Test. When sufficient material was available, standard reduced-section tensile specimens were prepared and tested. In these tests, ductility was measured over three different gage lengths centered at the weld, i.e., $^1/_2$ in., 1 in. and 2 in. This was done in order to define better the tensile ductility of the weld, heat-affected zone and base metal.

Corrosion Test. In order to determine if welding of carbon-containing titanium had an effect on corrosion resistance analogous to that of welding in stainless steels, representative samples of welded sheet containing 0.015, 0.264, 0.500 and 0.800% carbon were exposed to the following corrosive media for 240 hr.:

(*a*) 65% nitric acid, boiling (five 48-hr. periods).

(*b*) 1% Sulphuric acid, 80° C. (24-, 96-, 96-, 24-, hr. periods).

(*c*) 3% Hydrochloric acid, 80° C. (24-, 96-, 96-, 24-, hr. periods).

(*d*) 40% Sodium hydroxide, 80° C. (24-, 96-, 96-, 24-, hr. periods).

(*e*) 40% Cuprous chloride, boiling (24-, 96-, 96-, 24-, hr. periods).

(*f*) Saturated sodium chloride, boiling (24-, 96-, 24-, hr. periods).

Corrosion rates were calculated in inches penetration per month on the basis of average weight loss data, sample size and density.

Metallographic Studies

Metallographically polished and etched sections of all welds were examined to determine, if possible, what phases were responsible for the properties of the welds tested, and representative photomicrographs of these are included. These samples were etched for 2–5 sec. using a solution of 1 part 65% nitric acid, 1 part 48% hydrofluoric acid and 2 parts of glycerin at room temperature.

In addition, oxide replicas of the weld metal were prepared and examined by electron microscopy to determine if finer structure detail would shed more light on the interpretation of results. The electron microscope replicas were prepared by lightly oxidizing a polished and etched surface in a molten solution of sodium and potassium nitrate and then chemically stripping small squares ($^1/_8$ in.) of oxide from the sample surface by exposure of a scribed sample to a bromine-methanol solution (1 part bromine to 15 parts methanol). The small squares of oxide were washed in fresh methanol, supported on stainless steel screens and examined in the electron microscope.

The isolation of carbides and other nonmetallic phases in the weld metal was readily accomplished by dissolving away the base metal using a 1–15 solution of bromine in methanol; the insoluble nonmetallics were left behind as a residue. The residue was washed and dispersed on "Formvar screens" (200-mesh wire screens, $^1/_8$ in. diameter covered with a very thin film of "Formvar" resin). These phases were examined in the light microscope and the electron microscope. Electron diffraction patterns of these residues were also taken. Some of the residue from a weld sample containing 0.8% carbon was also dispersed on a glass slide and examined by electron and photomicrography.

RESULTS

Bend Test Data

Results of the bend test are given graphically in Fig. 1. This graph plots the angle of bend (in degrees from horizontal) to fracture against carbon content for as-welded samples. These data show that above about 0.25% of carbon, as-welded samples of titanium cannot consistently be bent 100° around pins of 3T or less bend radius without failure. As the carbon content increases, an increasingly lower bend ductility results. There is apparently no sharp break in the curve, although more data would be required to establish this fact with certainty. Samples with bend radii between 1.5 and 3.0T will, in general, fall within the scatter band shown. The criterion of a 1.5 to 3.0T bend radius results from the wide variety of sheet thicknesses which were used in this investigation. It is believed that the variety of thicknesses will not basically alter the shape of the curve. All samples failed either at the fusion line in the weld metal or in the center of the weld. Samples welded in the argon box by Linde, and those heat treated at 1400°, 1800°, 1900° and 2000° F. showed no consistent improved ductility over standard as-welded samples.

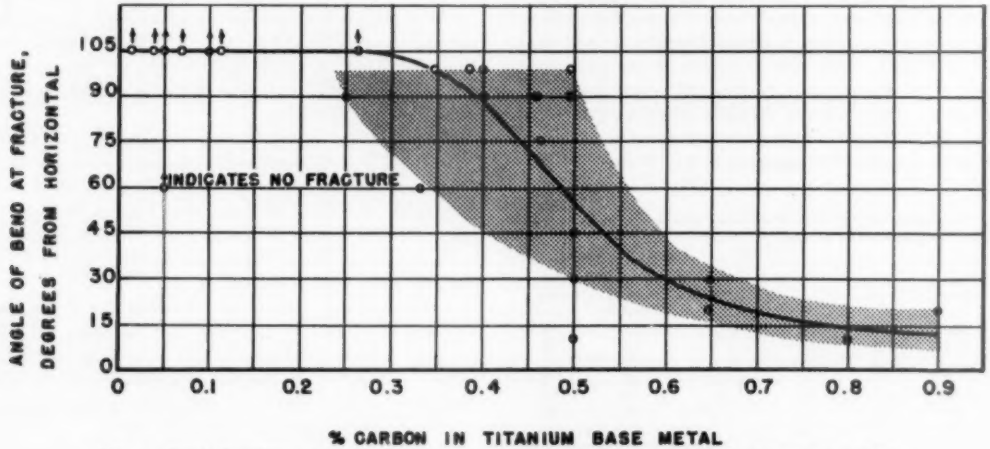


Fig. 1 Bend ductility of inert-gas tungsten arc-welded titanium strip (bend radii, 1.5—3.0 T)

Table 3—Tensile Test Data of As-Welded Titanium Sheet

Carbon content, %	Welded: Ultimate strength, psi	Welded: 0.2% Yield strength, psi	Welded: Elongation % in 1/2–1–2 in.	Unwelded base metal: Ultimate strength, psi	Unwelded base metal: 0.2% Yield strength, psi	Unwelded base metal: Elongation %, 1/2 in.
0.040	91,800*	77,000	8–20–18	80,000	69,000	25
0.068	78,800*	59,400	8–19–17	...	...	...
	60,800*	...	4–10–18	...	...	...
0.113	68,000*	51,800	0– 9–19	...	...	...
	71,200	55,300	8– 7– 9	...	...	...
0.345	76,000*	69,700	4–12–18	79,000	...	27
	82,500	74,700	8–17–16	...	...	...
0.385	78,400*	64,800	6–19–16	...	...	...
0.400	111,800	101,200	4– 4– 2	...	...	...
0.465	99,400	88,200	10– 9– 5	91,300	77,700	24
0.495	90,000	75,300	10–14–11	80,000	74,000	26
	81,500	...	4– 3 –2	...	...	...
0.500	89,000	83,000	4– 5 –2	...	...	...

* Fractured in base metal.

Tensile Test Data

The tensile test data are given in Table 3. Unfortunately, insufficient stock was available to get tensile data on all the as-welded materials, and very few data are available on the as-received stock. However, from the data presented in Table 3, it appears that welding results in decreased ductility in all cases, and that the tensile strength is not significantly affected by welding. Up to about 0.40% carbon, most of the failures occurred in the base metal. It is generally true that the shorter the gage length in a tensile test, the greater the ductility. In these results it appears that the reverse is true in most instances. Presumably this is due to the limited ductility of the cast weld structure.

Corrosion Test Results

Results on the corrosion resistance of titanium welds compared to base metal on samples having representative carbon contents are given in Table 4. These data show that, in general, an increase in carbon content improves the corrosion resistance of both the base metal and the weld metal. They further show that when the base metal is unattacked, the weld metal is similarly unaffected. In the case of the 0.264% carbon sample, the weld metal was subject to significantly more severe attack than the base metal in 1% sulfuric acid and 3% hydrochloric acid.

Metallographic Results

Typical microstructures of base metal and weld metal are given in Figs. 2 through 5. Figure 2 (*A*) shows the base metal of the 0.015% carbon alloy at 400 ×. The base metal is annealed and shows a typical coarse-grained α-titanium structure. There is some evidence of a second phase in the grain boundaries of this material. Figure 2 (*B*) illustrates at 400 × the weld-metal structure. A typical Widmanstätten transformation structure is evident, and no conclusive evidence of a second phase is apparent.

Figure 3 (*A*) represents the annealed base-metal structure of the 0.264% carbon material. Some large globular carbides are evident in this sample, along with a large number of small particles. It is not known whether these small particles are carbides. In Figure 3 (*B*) the weld metal structure of this same alloy is shown. The sample is lightly etched so that only a sharp etching phase (presumably carbide) shows up in the α base metal. This phase is finely divided and dispersed in a somewhat regular fashion.*

Figure 4 (*A*) shows the base metal of the 0.495% C sample. This sample was hot rolled and annealed and the micrograph at 750 × shows large globular carbides and α-titanium, as well as a dispersed additional phase, roughly oriented in the direction of rolling. The structure shown in Figure 4 (*B*) is representative of the heat-affected zone of this sample close to the weld. In this area, the transition temperature (α-β) has been exceeded as indicated by the Widmanstätten structure. The carbides appear to be unchanged, but the additional phase evident in Fig. 4 (*A*) appears to have gone into solution and to have reprecipitated in

* It is speculated that this represents precipitation of the carbide phase in the Widmanstätten planes during cooling of the β-phase.

Table 4—Influence of Carbon Content on Corrosion Rate of As-Welded Titanium

Carbon content, %	Sample	Corrosion rate in./mo., 240 hr. exposure: 65% Nitric, boiling	1% Sulphuric, 80° C.	3% Hydrochloric, 80° C.	40% Sodium hydroxide, 80° C.	40% Cupric chloride, boiling	Sat'd Sodium chloride, boiling
0.015	Base metal	0.00189	0.0200	0.0168	0.00034	No attack	No attack
	Welded strip	0.00107	0.0173	0.0162	0.00033	No attack	No attack
0.264	Base metal	0.00059	0.00570	0.00360	0.00034	No attack	No attack
	Welded strip	0.00075	0.0146	0.0125	0.00026	No attack	No attack
0.500	Base metal	0.00069	No attack	No attack	0.00030	No attack	No attack
	Welded strip	0.00082	No attack	No attack	0.00032	No attack	No attack
0.800	Base metal	0.00073	No attack	No attack	0.00027	No attack	No attack
	Welded strip	0.00072	No attack	No attack	0.00027	No attack	No attack

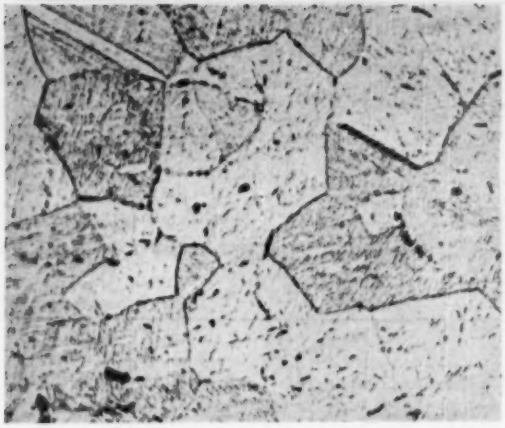


Fig. 2 (A) Base metal, 0.015% C, annealed, 400 ×

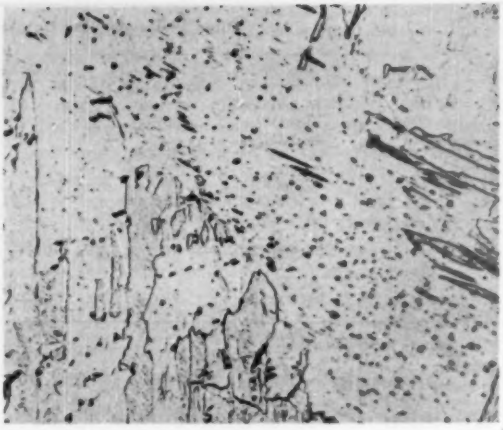


Fig. 2 (B) Weld metal, 0.015% C, as-deposited, 400 ×

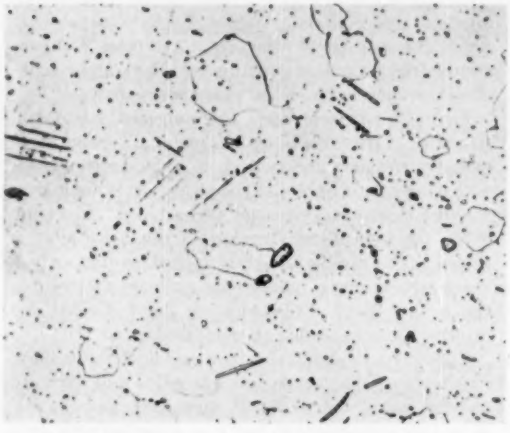


Fig. 3 (A) Base metal, 0.264% C, annealed, 411 ×

Fig. 3 (B) Weld metal, 0.264% C, as-deposited, 400 ×

Fig. 4 (A) Base metal, 0.495% C, annealed, 750 ×

Fig. 4 (B) Base metal transition zone, 0.495% C, 750 ×

Fig. 4 (C) Weld metal, 0.495% C, as-deposited, 750 ×

the grain boundaries and in plate form along the β lattice planes. Figure 4 (*C*) shows the weld metal at 750 ×. This structure appears to be one of a dendritic carbide phase distributed throughout the cast weld-metal matrix. The background is again a typical Widmanstätten structure.

Figure 5 (*A*) (400 ×) illustrates the structure of pack rolled 0.8% C titanium. A large number of globular carbides are evident as well as an additional phase outlining the α-titanium grains. These carbides appear to have a duplex structure. Figure 5 (*B*) shows the fusion line in this sample at the same magnification. Globular carbides are evident at one side of this photomicrograph while carbides, which appear to be dendritic, are evident at the other side. The weld metal is further illustrated in Figure 5 (*C*) (400 ×). In this figure the geometric form of the carbide phase is even more evident. Figure 5 (*D*) shows the fracture of the bend-test sample in this material at 400 ×. The fracture follows the carbide phase.

Figure 6 summarizes the light and electron microscope attempt to study the nonmetallic carbide phase in the weld metal. The photomicrograph, Figure 6 (*A*), shows a typical dendritic carbide in the weld metal of the 0.8% carbon sample (magnification 725 ×). Figure 6 (*B*) shows an electron micrograph at 2650 × of an oxide replica taken from the 0.264% carbon sample. A large and complex carbide dendrite is shown in this figure against a background Widmanstätten structure. There is again some evidence of a second phase within this Widmanstätten structure. Figure 6 (*C*) (2650 ×) shows an electron microscope picture of isolated carbides from the 0.264% carbon sample. The large dendrites are the carbides, while the fine fibrous background material is unidentified. Figure 6 (*D*) is a light micrograph at 500 × of the isolated carbides from the 0.8% carbon sample. The similarity in form of the carbides in all these pictures is evident.*

* It appears that at least the carbides from the 0.8% C alloy formed from the melt. If this is so, it means that the eutectic point falls below 0.8% carbon. This evidence is not positive because dendritic precipitation can occur from the solid state. However, such precipitation from the solid is usually essentially two dimensional and is ordered by the base lattice.

Fig. 5 (A) Base metal, 0.8% C, pack rolled, 400 ×

Fig. 5 (B) Fusion line between weld and base metal, 0.8% C, 400 ×

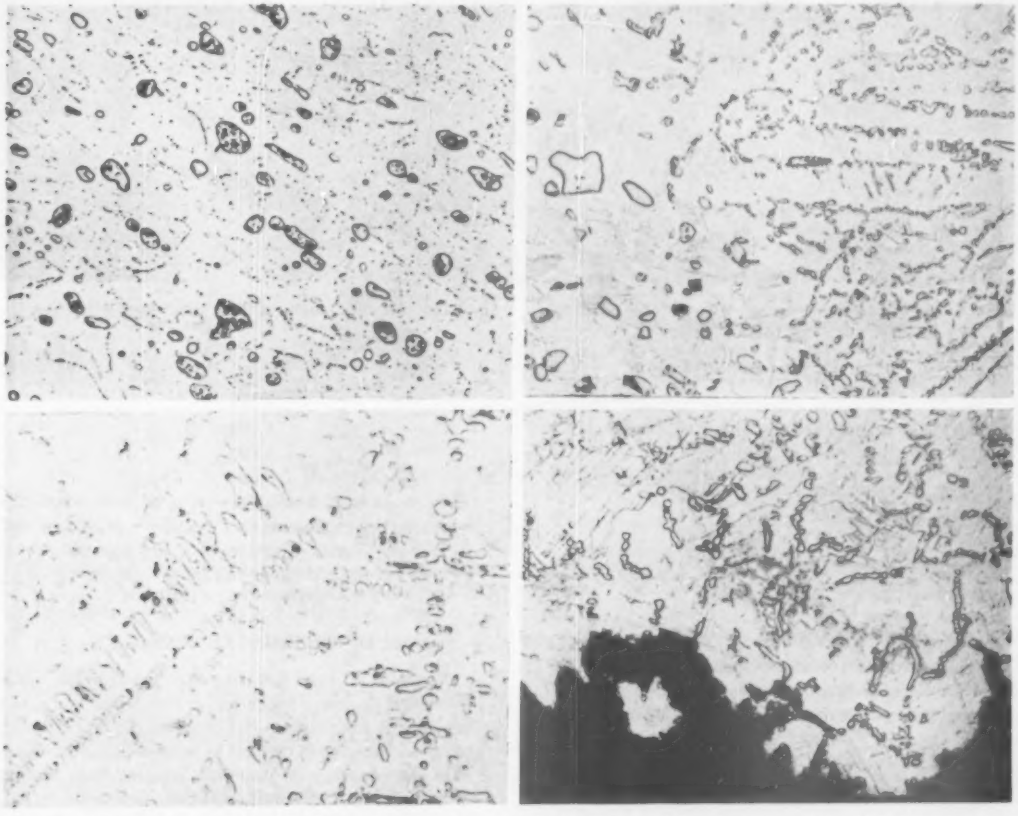
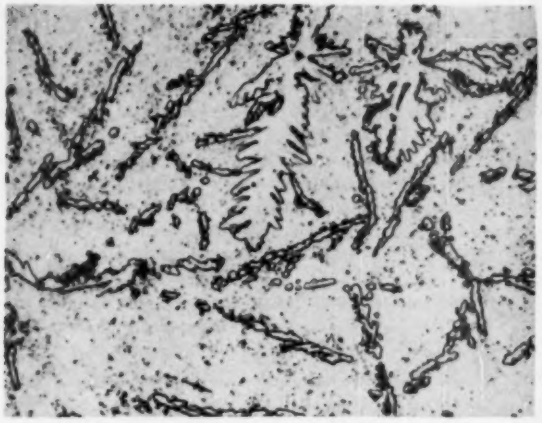


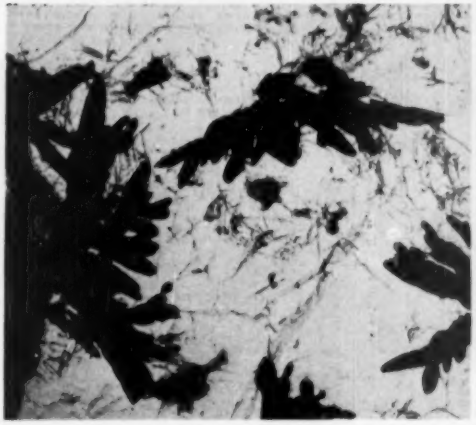
Fig. 5 (C) Weld metal, 0.8% C, as-deposited, 400 ×

Fig. 5 (D) Bend fracture through weld, 0.8% C, 400 ×

Fig. 6 (A) Weld metal, 0.8% C, as-deposited, 725 ×

Fig. 6 (B) Electron micrograph of oxide replica of 0.264% C bearing titanium weld metal, 2650 ×





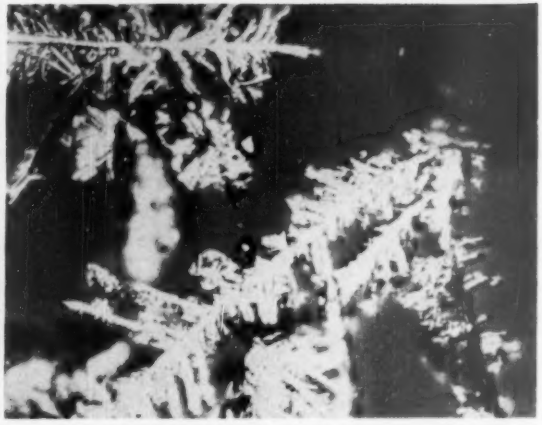


Fig. 6 (C) Electron micrograph of carbide from 0.264% C bearing titanium weld metal, 2650 ×

Fig. 6 (D) Photomicrograph of carbide from 0.8% C bearing titanium weld metal, 500 ×

Electron diffraction patterns of the two phases isolated from these samples have been taken. The large dendritic structure gave the following d spacings:

d	
2.570	1.290*
2.500*	1.23 *
2.240	1.13
2.150*	1.03
1.585	0.995*
1.520*	0.964*
1.350	0.880*

The starred (*) d values match those of TiC. The fibrous material gave the following d values. The four strongest lines are indicated:

d
2.595 (1)
2.240 (3)
1.580 (2)
1.350 (4)
1.285
1.120
1.025
1.000

This constituent has a face-centered cubic structure with a lattice parameter that calculates to be $a_o = 4.47$ Å. This material is unidentified. It does not appear to be a known carbide or nitride.

DISCUSSION OF RESULTS

The data on bend ductility and tensile properties of as-welded titanium presented in this report indicate a continuous reduction in the bend ductility of titanium welds as the carbon content is increased. No measurable improvement in properties resulted from welding in an argon box, or from short-time post-welding heat treatments. This continuous decrease in ductility

appears to result from the larger quantity of dendritic carbide found in the weld as the carbon content of the alloys is increased. In all cases, failure of the bend samples occurred in the weld metal and, in most cases, at the fusion line. When enough carbide was present for the phase to be evident in the photomicrographs, the failure appeared to be through that phase. There is no evidence that the carbide phase exists at the α grain boundaries in the weld, but it appears to be associated with some prior phase grain boundary, perhaps β, and in most cases it appears to be dendritic itself and to outline the existence of a prior dendrite phase.

The interpretation of these data is definitely handicapped by the lack of reliable constitution information on the titanium-carbon system, and a valid explanation of these results will have to await such information. In any event, the damaging phase in these alloys has been isolated and proved to be carbide. From the corrosion data (Table 4) it is apparent that in those services where titanium has adequate corrosion resistance for practical use, the welds of titanium containing up to 0.8% C will also have suitable corrosion resistance.

It appears fortunate that the carbide phase in these alloys is not associated with the α-titanium grain boundaries, otherwise it is believed that the reduction in ductility would be even more pronounced, and it could have been expected that the corrosion resistance of these alloys would be adversely affected by welding.

CONCLUSIONS

(1) The inert-gas shielded tungsten arc process is satisfactory for welding titanium-carbon alloys.

(2) Increasing carbon in titanium-carbon alloys results in a continuously decreased bend and tensile ductility of as-welded samples. A carbon content of the order of 0.25% cannot be exceeded if ductile 3T bends are required in the as-welded condition.

(3) Decreased ductility results from the presence of a dendritic phase identified by electron diffraction to be TiC.

(4) In those cases where the corrosion resistance of titanium is sufficiently good to justify its use economically, welded stock containing carbon from 0.015 to 0.8% is essentially as corrosion resistant as the unwelded base metal.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the cooperation of the Linde Air Products Co. in providing some of the welded samples, the furnishing of material by the Pigments Department of E. I. du Pont de Nemours & Co. and the Remington Arms Co. and the assistance of other members of the Engineering Research Laboratory. In particular, the weld residues were isolated and photographed by N. A. Nielsen, and the corrosion test results were supplied by P. H. Permar.

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Rules of Procedure for Project Committees

Welding Research Council

THESE rules of procedure are intended as a guide to Project Committees, rather than as rigid inflexible requirements. The important thing is to get the task done well as quickly as possible and with a minimum cost.

Project Committees should be as small as possible with adequate representation from the contributors, the research workers and the needed scientific talent.

MEMBERSHIP

With the exception of representation from the contributing interests, membership on Project Committees and their Subcommittees involves active participation. Inactive members should be asked to resign. If membership representation is because of company connection then when an individual leaves that company his membership terminates and the organization is asked to appoint a new member. Old members may be retained, however, if particularly able.

MEETINGS

Attention is called to the By-laws of the Council re-

(*Continued on page 564-s*)

Welding Air-Hardening Alloy Steels

The investigation of various procedures for the shielded metal-arc welding of an air-hardening alloy steel indicated that the isothermal transformation characteristics of the heat-affected zone considerably influenced the weldability of the material under high restraint

by Walter H. Wooding

Abstract

The investigation of various procedures for the shielded metal-arc welding of an air-hardening alloy steel indicated that the isothermal-transformation characteristics of the heat-affected zone considerably influenced the weldability of the material under high restraint. The restraint imposed required utilization of preheat and interpass temperatures exceeding that temperature at which the martensite transformation begins on cooling the material from the austenitizing temperature. At such preheat and interpass temperatures, it was found that satisfactory restrained weldments could be obtained only by maintaining the temperature as a postheat for a suitable length of time. When the scarf surfaces were clad with weld metal prior to the deposition of the butt weld and the accompanying restraint, satisfactory weldments were obtained at relatively low preheat and interpass temperatures.

These observations led to a study of the isothermal-transformation characteristics of the heat-affected zone of single-pass welds deposited on this material. The results indicated that above the temperature at which the martensite transformation begins, the heat-affected zone is very sensitive to thermal shock and prone to underweld cracking. This cracking persists until the bainite transformation approximates 8%. Heat-affected zones exhibiting partial martensite transformation are likewise sensitive to underweld cracking unless they are subsequently tempered prior to thermal shock.

Studies were also made of the effect of preheat upon the cooling rates of heat-affected zones of air-hardening alloy steel. Data indicate that the initial cooling rate resulting from the quench effect of the base plate is not materially retarded by increases in preheat temperature.

INTRODUCTION

THE shielded metal-arc welding of air-hardening alloy steels generally provokes considerable concern as to the suitability of a prescribed welding procedure to produce satisfactory weldments. Too often, the procedure, usually established as a result of small-scale welding tests, fails to produce field weldments of anticipated quality, particularly where extreme rigidity is developed in the structure because of its size and shape. A most common defect found in such weldments is underbead cracking; and, its occurrence has been attributed to a combination of factors including the presence of hydrogen in the arc atmosphere and the hardenability of the base metal.* It is the general opinion that by the control of these two factors; i.e, using a low-hydrogen type electrode, particularly one depositing a chromium-nickel alloy-austenitic steel, and using a preheat sufficiently high in temperature to materially retard the cooling rate of the heat-affected zone, underweld cracking may be avoided. (Provided the external stresses developed in the joint are not excessive.)

It was with due consideration of the above, that efforts were made to establish a satisfactory procedure for the shielded metal-arc welding of nickel-chromium-molybdenum alloy-steel plate $3^3/_4$ in. thick. This material was for use in fabricating a large rigid structure similar to one previously erected without undue difficulty using a nickel-chromium alloy steel of the same thickness. In view of the success with which the latter material has been utilized, it was considered advisable to establish a procedure for welding the nickel-chromium-molybdenum alloy steel at the maximum level of restraint under which the nickel-chromium-alloy steel could be successfully welded. It was the opinion that this could be accomplished through the use of the restrained circular-groove weld test or so-called "Navy Patch Test." The use of this test would require welds of dimensions greater than those normally encountered in ordinary laboratory tests; and, at the same time would provide means for adjustment over a wide range of restraint across the weld.

MATERIALS

The chemical composition of the nickel-chromium-molybdenum steel plate of which this investigation is concerned, is given in Table 1. The composition of the nickel-chromium steel is also included for comparison. Both materials are in the quenched and tempered condition and have a hardness in the range of 200–230 Brinell.

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This paper presents only the personal opinions of the author and in no way reflects the official attitude of the U. S. Navy. Published by permission of the Navy Department.

* Voldrich, C. B. "Cold Cracking in the Heat-Affected Zone." THE WELDING JOURNAL **26** (3), Research Suppl., 153-s to 169-s (1947).

Table 1—Chemical Composition of Materials

Element	*Ni-Cr-Mo* Steel, %*	*Ni-Cr†S steel, %*
Carbon	0.42	0.30
Manganese	0.38	0.21
Silicon	0.15	0.05
Nickel	3.60	3.22
Chromium	2.30	1.30
Vanadium	0.01	...
Molybdenum	0.43	...

* Hereinafter referred to as steel Type A.
† Hereinafter referred to as steel Type B.

The deposition of all welds reported herein was accomplished using $^3/_{16}$-in. diameter Type 310 chrome-nickel (25–20) austenitic-steel electrodes, specifically purchased so that the entire quantity was obtained from the same lot; that is, the same core wire and batch of covering mix. When received, the electrodes were subjected to test to determine their conformity to the requirements of Navy Department Specification 46E4 for Grade IV D.-C. material. As shown in Table 2, the chemical composition of the weld deposit and results of the "Navy Torture Test" are in strict conformity with the requirements of that specification. Throughout the duration of this investigation, the electrodes were carefully stored in unopened containers in dry storage until used.

PROCEDURE

The restrained circular-groove weld test or "Navy Patch Test" consists of the welding of a plug in a hole located in the center of a plate of fixed dimensions. The restraint imposed upon the butt weld attaching the plug to the plate may be varied by change in the outside dimensions of the plate or the mean diameter of the circular groove weld. Those assemblies which when subjected to X-ray examination, fail to show evidence of cracking in or adjacent to the weld are considered to indicate the suitability of a welding procedure for obtaining a satisfactory butt weld under the conditions of restraint imposed by such assemblies. The suitability of various materials for welding under comparable degrees of restraint is determined by the modification of welding procedures to obtain satisfactory welds in assemblies of identical dimensions.

The restrained circular-groove tests used in this investigation were conducted as follows:

Samples 20-in. square were cut from plate materials under test and prepared for circular-groove weld assemblies by machine flame cutting to the shape and dimensions given in Fig. 1. For the various assemblies for each material, the mean diameter D of the circular groove was changed from 4 to 8 in. in 1-in. steps. For each change in the mean diameter of the circular-groove weld, duplicate assemblies of each material were prepared for each condition of welding. Backing rings of the same mean diameter and 1 in. wide were cut from 20-lb. medium steel plate for each assembly. The ring was welded to the root side (bottom) of the plate and patch with a full $^1/_4$-in. fillet around both the inner and

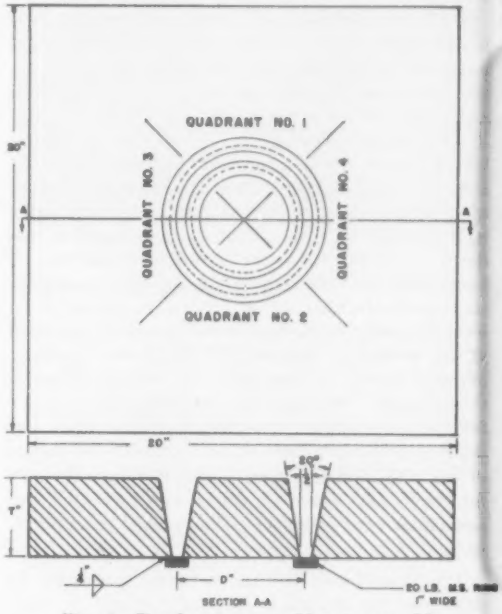


Fig. 1 Circular-groove weld-test assembly

Table 2—Properties of Chrome-Nickel Austenitic Steel Type 310 (25–20) Welding Electrodes

Chemical Composition of Deposited Weld Metal

Electrode size	*C*	*Mn*	*P*	*S*	*Si*	*Ni*	*Cr*	*Mo*
	Per cent							
$^3/_{16}$ in. Diameter	0.11	1.74	0.024	0.010	0.39	21.35	25.83	0.06
Spec. requirement	0.09	1.0	Max.	Max.	Max.	Min.	Min.	Min.
	0.20	2.5	0.030	0.030	0.80	20.00	25.00	0.25

Physical Characteristics—Restrained-Groove Weld Test (Navy Torture Test)

Electrode size	*Welding position*	*X-ray results*	*Specimen location*	*Yield strength, psi.*	*Tensile strength, psi.*	*Elong. % in 2 in.*	*Location of fracture*
$^3/_{16}$ in. Diameter	Vertical	Satisfactory	Root	67,200	99,600	9.8	Bond and weld
			Face	73,900	95,800	10.0	Weld
			Face	67,200	95,700	12.5	Weld
			Root	78,300	100,800	9.3	Bond and weld
Spec. requirement			Face and root	...	Min. 85,000	Min. 7	...

outer circumferences of the ring using 25–20 chrome-nickel austenitic-steel welding electrodes. For the attachment of all backing rings a preheat of 250° F. was used to preclude the initiation of any failures from this preliminary operation.

The groove welds were deposited using the block technique in which each quadrant of the circular groove was designated as a block and each block completely welded before starting the next. The sequence used in the welding of the blocks was that after completion of the first block the block diametrically opposite was welded next, the third and fourth blocks being completed in the like manner.

All welds were deposited in the flat position using a split-weave technique. Weaving was restricted in magnitude from $2^1/_2$ to 3 times the electrode diameter which permitted the first two layers of weld metal in each assembly to be deposited with a full weave.

Duplicate assemblies were prepared for each condition of preheat and interpass temperature. Preheat and interpass temperatures were maintained by the use of a specially constructed jig equipped with heating coils and automatic-temperature controls, as shown in Fig. 2. The entire assembly was brought to and maintained at the desired preheat temperature within ±5° F. When interpass temperatures were controlled, after deposition of each pass, and before proceeding with the next pass, the assembly was allowed to cool down to, but not below the desired temperatures and, held thereat until the temperature of the entire assembly was equalized within ±5° F. Upon completion of the weld, the assembly was held in the jig until equalization at the prescribed temperature; which was generally accomplished in approximately 1 hr. after deposition of the last pass. The completed assemblies were prepared for X-ray examination by machining off the weld backing ring and weld reinforcement flush with the surface of the plate. The prepared assemblies were X-rayed for cracks and where no cracks were indicated, the assemblies were sectioned and examined macroscopically.

The Type B steel was first subjected to this test to determine the maximum level of restraint at which satisfactory welds could be deposited under conditions normally encountered in production welding; that is,

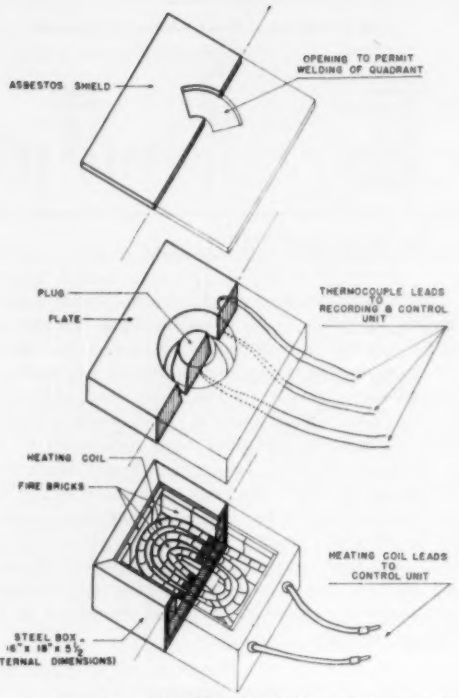


Fig. 2 Apparatus for obtaining preheat and interpass temperature

a preheat temperature of from 70 to 100° F. and an uncontrolled interpass temperature of 300° F. maximum. In the test, however, the interpass temperature was not permitted to drop below 100° F. The results of these tests, which are given in Table 3, indicate that the maximum level of restraint for satisfactory welding is somewhere between the 5- and 6-in. patch diameter.

Having established the desired maximum level of restraint at the 6-in. patch diameter, attempts were made to weld the Type A steel under such restraint using various conditions of preheat and interpass temperatures. The results of these tests are also given in Table 3 and indicate that a preheat of 600° F. and an

Table 3—Results of Circular-Groove Weld Test (Navy Patch Test)

Assembly No.	*Preheat temp., °F.*	*Interpass temp., °F.*	*Results of X-ray examination, patch diameter, in.* 4	5	6	7
			Nickel-chromium steel, type B			
1	70 to	Uncontrolled	....	Cracked 33%	No cracks	....
2	100	300° F. Max.	Cracked	Cracked 25%	No cracks	....
			Nickel-chromium-molybdenum steel, type "A"			
1	70 to	Uncontrolled	....	Cracked 100%*	....	Cracked 100%*
2	100	300 Max.	....	Cracked 100%*	....	Cracked 100%*
1	200	200 to	....	Cracked 20%	Cracked 20%	No cracks
2	200	300	....	Cracked 20%	Cracked 20%	No cracks
1	400	400 to	Cracked 20%	Cracked 25%	Cracked 10%	....
2	400	500	Cracked 20%	Cracked 25%	Cracked 15%	....
1	600	600 to	No cracks	No cracks	No cracks	No cracks
2	600	700	No cracks	No cracks	No cracks	No cracks

* Assembly cracked upon completion of first quadrant.

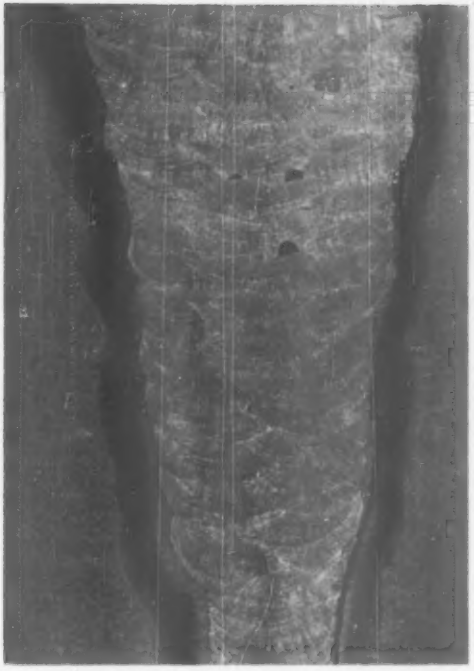


Fig. 3 Photomacrograph of transverse section from restrained circular-groove weld assembly

Preheat temp., 400° F.; patch diameter, 6 in.; interpass temp., 400–500° F.; magnification 1½ ×

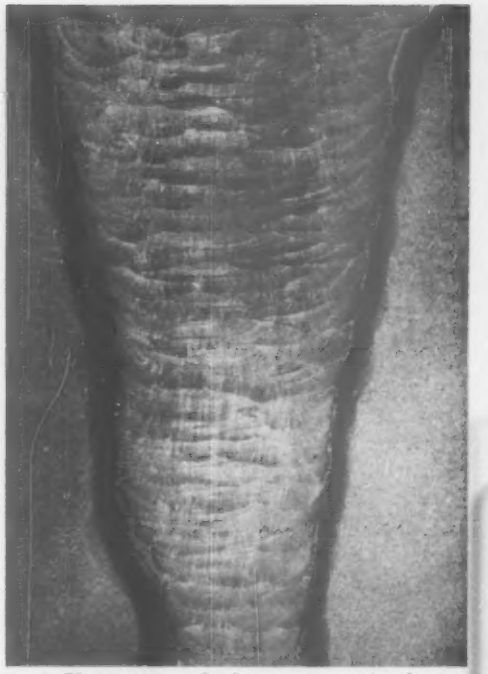


Fig. 4 Photomacrograph of transverse section from restrained circular-groove weld assembly

Preheat temp., 600° F.; patch diameter, 6 in.; interpass temp., 600–700° F.; magnification 1½ ×

interpass temperature of 600 to 700° F. are required. However, under these conditions, the results indicate that the restraint can be greatly increased (patch diameter reduced to 4 in.) without adverse effect upon the quality of the weld. Macrographs of transverse cross sections of welds removed from two assemblies are shown in Figs. 3 and 4.

Because of the excessively high preheat and interpass temperatures required to obtain satisfactory welded assemblies for the Type A steel, the patch test was modified so as to include clad-type joints. This was accomplished by first depositing a layer of weld metal over the entire scarf faces of the butt joint and then depositing the butt weld in the usual manner.

The clad-type restrained circular-groove weld test was conducted as follows:

Samples 20 in. square were cut from the Type A steel plate and prepared for circular-groove weld assemblies by machine flame cutting as previously described except that the root opening was increased from ½ to ¾ in. to provide space for the cladding layers. For these assemblies, the mean diameter of the groove was maintained at 6 in., the level of restraint, at which it was found that the Type B steel could be welded under normal conditions.

The scarf faces of the grooves were cladded using 3/16 in. diameter 25–20 chrome-nickel electrodes at several preheat and interpass temperatures. The depth of clad on each scarf face approximated ⅛ in.

Without further preparation of the clad surfaces, the component parts were assembled for welding and the groove weld deposited as previously described. Several preheat and interpass temperatures were used in the welding of various assemblies. Upon completion of the weld, the assemblies were X-rayed and examined macroscopically.

The conditions under which these tests were conducted together with the results thereof are given in Table 4. As indicated, the cladding method appears to produce satisfactory welds at relatively low preheat and interpass temperatures. A macrograph of a trans-

Table 4—Results of Circular-Groove Weld-Test Clad Scarfs (Navy Patch Test)

Nickel-Chromium-Molybdenum Alloy Steel, Type A

	Temperature, ° F.				
	Preheat		Interpass		
Assembly No.	*For cladding*	*For depositing groove weld*	*For cladding*	*For depositing groove weld*	*Results of X-ray examination, 6 in. diameter patch*
1	200	200	200 to 300	200 to 300	No cracks
2	...	...	...	...	No cracks
1	250	70 to 100	250	150	No cracks
2	...	...	...	Max.	No cracks
1	200	70 to 100	200	150	No cracks
2	...	...	...	Max.	No cracks
1	150	70 to 100	150	150	No cracks
2	...	...	...	Max.	No cracks

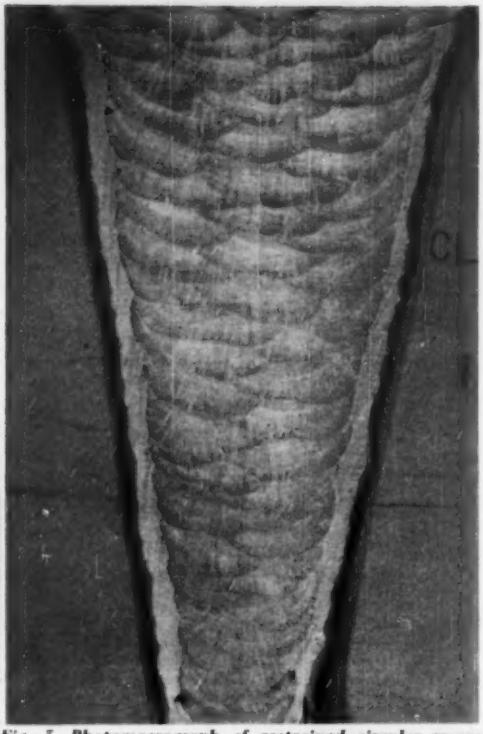


Fig. 5 Photomacrograph of restrained circular-groove weld-test assembly clad-type joints

Preheat temp., room temp.; patch diameter, 6-in.; interpass temp., 150° F.; cladding preheat temp. 150° F.; magnification 1½ ×

verse cross section through the weld of one of the cladded assemblies is shown in Fig. 5.

Both welding procedures found satisfactory for welding the Type A steel in the circular-groove restrained weld test were recommended to production activities for further check. It was found that when the 600° F. preheat and 600–700 F. interpass temperatures were used cracking was encountered in the heat-affected zones. The cladding method, however, produced satisfactory weldments. A further check on the procedure used for the unclad butt welds indicated that the preheat temperature of the assembly was not maintained after completion of the weld as had been done in the Navy Patch test.

This observation gave rise to the opinion that the thermal behavior of the material might be associated with the variation in results obtained by the production activities and the laboratory. It was therefore considered desirable to extend the investigation to include a study of the thermal behavior of the Type A steel consisting of temperature-dilation data, Jominy end-quench hardenability data, and time-temperature-transformation characteristics of the heat-affected zone of single-bead weld deposits.

The temperature-dilation characteristics of both the types A and B steels were determined using a Rockwell Bristol Dilatometer. A specimen $^1/_2$ in. in diameter by 2 in. long was heated at a constant rate of 400° F. per hour to 1700° F. Upon reaching this temperature, the specimen was quenched in circulating oil to room temperature. During the heating and cooling cycles, an automatic graphic record was made of the temperature and longitudinal dilation of the specimen. The results of this test are presented in Fig. 6.

The Jominy end-quench hardenability was determined using a standard specimen 1 in. in diameter by $3^7/_8$ in. long. This test was conducted as outlined in the "Guide to Weldability of Steels" proposed by the Welding Research Council of the Engineering Foundation. Specimens of both types A and B steels were heated to 2100° F., held at temperature for $^1/_2$ hr. and immediately quenched in the standard Jominy-Bar Quenching Apparatus. Rockwell "C" scale-hardness values were obtained at intervals throughout the length of the specimens and plotted on a standard A.S.T.M. Jominy End-Quench Hardenability chart. Though the above mentioned "Guide to Weldability of Steels" requires that this test be done in triplicate, the results obtained for the one specimen of each steel and presented in Fig. 7 are not considered to warrant further tests of this type.

The investigation to determine the isothermal transformation characteristics developed in the heat-affected zone adjacent to single-pass welds was conducted as follows:

Specimens 2 x 1 x $^3/_4$ in. were cut from the Type A steel plates with the 2-in. dimension parallel to the longer axis of the plate and the $^3/_4$-in. dimension parallel to the depth of the plate. The specimens were cleaned of scale, surface decarburization and other foreign matter prior to use.

A single-bead weld, 1 in. long, was deposited parallel to the 2-in. dimension in the center of a 2- x 1-in. face of each specimen using automatic-voltage control welding equipment. Welds were deposited under constant welding conditions of 175-amp., 24-arc volts and an arc travel speed of 6 in. per minute using $^3/_{16}$-in. diameter 25–20 chrome-nickel welding electrodes.

Prior to welding, the specimens were preheated by being submerged for 1 hr. in an automatically controlled salt bath maintained at the following temperatures: 900, 800, 700, 600, 500, 450, 435 and 415° F. Specimens for each preheat temperature were singly removed from the salt bath after 1-hr. submergence, quickly transferred to the welding jig, the weld bead deposited and then immediately returned to the salt bath where they were held for various periods of time, ranging from 2.5 to 400 min. and from 18 to 120 hr. Upon completion of the time interval in the postheat bath, the specimens were removed and immediately quenched in iced water maintained at 32° F. In addition, specimens were preheated to 400, 375, 325, 275, 225 and 175° F. welded in the same manner, quickly returned to the preheat bath and held there for 10 min., after which they were quenched to 32° F.

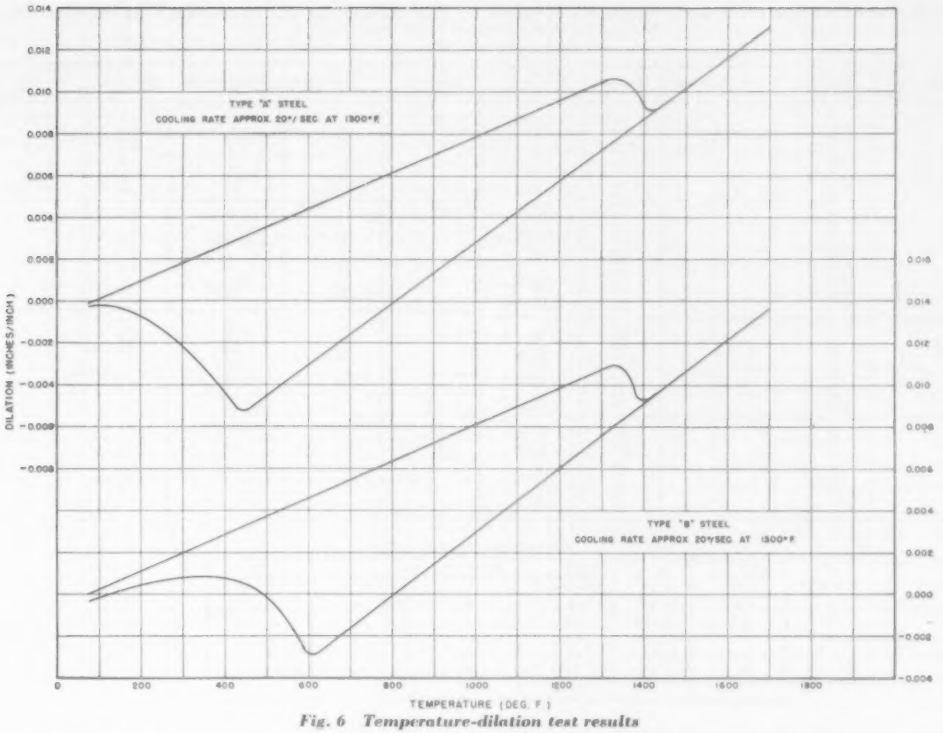


Fig. 6 Temperature-dilation test results

The martensitic transformation characteristics were also determined as outlined above using preheat and postheat temperatures of 400, 375, 325, 275, 225 and 175° F. Immediately upon completion of the weld deposit, the specimens were quenched back to the preheat temperature by being submerged in the heating bath for 10 min.; after which they were immediately tempered at 850° F. for 30 min. and water quenched to 32° F.

Immediately upon being brought to room temperature, all specimens were sectioned in a plane normal to the axis of the weld bead at its center and the surface carefully prepared for metallographic examination. The prepared surfaces were etched with 2% nital and examined at a magnification of 200 diameters. The per cent of transformation product occurring in the heat-affected zone immediately adjacent to the weld beads was estimated to provide data to establish the time-temperature-transformation relationship for the Type A steel when subjected to the welding cycle.

The time-temperature-transformation characteristics observed in the heat-affected zone of single-pass welds deposited on the Type A steel are tabulated in Table 5. During the conduct of this portion of the test, underbead cracking was observed in the heat-affected zone of a number of specimens and these data have been included in Table 5. Also included are maximum Rockwell 30 "N" scale-hardness readings taken in the heat-affected zone of a number of the

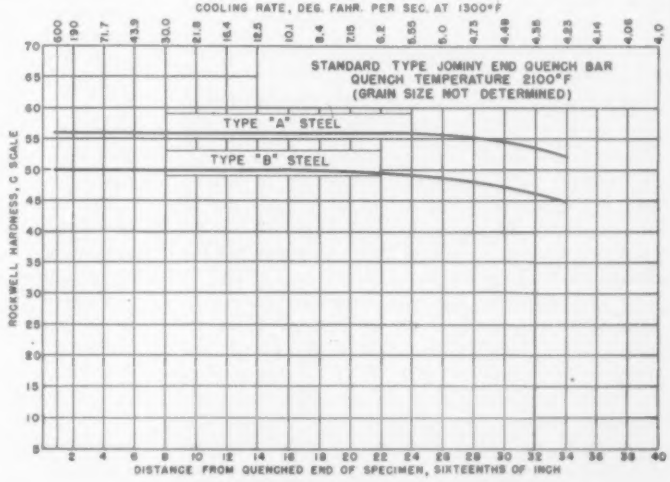

COOLING RATE, DEG. FAHR. PER SEC. AT 1300°F
STANDARD TYPE JOMINY END QUENCH BAR
QUENCH TEMPERATURE 2100°F
(GRAIN SIZE NOT DETERMINED)
TYPE "A" STEEL
TYPE "B" STEEL
ROCKWELL HARDNESS, C SCALE
DISTANCE FROM QUENCHED END OF SPECIMEN, SIXTEENTHS OF INCH

Fig. 7 End-quench hardenability test results

Table 5—Time-Temperature-Transformation Characteristics. Heat-Affected Zone of Single-Pass Weld Deposits. Nickel-Chromium-Molybdenum Alloy Steel Type A

TYPE "A"

Temperature Deg.Fahr.	Time at Temperature Minutes	Transformation Product - %	Underbead Cracking	Maximum Rock.Hard. 30 "N" Scale
900	1	0	Yes	79-1/2
	100	0	Yes	79
	1440	Trace	Yes	80
800	1440	0	Yes	--
700	1	0	Yes	78-1/2
	10	0	Yes	79-1/2
	30	0	Yes	81
	30	0	Yes	80
	60	0	Yes	80
	90	0	Yes	80-1/2
	180	0	Yes	78-1/2
	400	Trace	Yes	80
	1080	2	Yes	80
	1560	3	Yes	80
	2880	3	Yes	79-1/2
	4320	4	Yes	80
	5760	5	Yes	80
	7200	8	No	80
600	1	0	Yes	79
	10	Trace	Yes	79
	20	2	Yes	80
	30	8	No	78-1/2
	60	10	No	78
	90	12	No	77-1/2
	180	30	No	77
	400	85	No	65
	1440	--	No	--
500	1	0	Yes	77
	10	0	Yes	77-1/2
	20	0	Yes	78-1/2
	30	Trace	Yes	79
	60	5	Yes	78
	90	15	No	78-1/2
	180	60	No	77
	400	95	No	72
	1440	100	No	70

Temperature Deg.Fahr.	Time at Temperature Minutes	Transformation Product - %	Underbead Cracking	Maximum Rock.Hard. 30 "N" Scale
450	1	0	Yes	79-1/2
	10	0	Yes	80
	30	Trace	Yes	80
	30	5	Yes	80-1/2
	60	15	No	78
	90	30	No	77-1/2
	180	50	No	76-1/2
	400	100	No	76
435	2.5	0	Yes	--
	5	0	Yes	--
	15	0	Yes	--
	20	Trace	Yes	--
	30	4	Yes	--
	60	5	Yes	--
	90	7	Yes	--
	180	20	No	--
	390	75	No	--
	1440	98	No	--
415	2.5	0	Yes	--
	10	0	Yes	--
	60	Trace	Yes	--
	250	30	No	--
	1440	95	No	--
400	10	0	Yes	--
375	10	0	Yes	78
325	10	0	Yes	--
275	10	0	Yes	76
225	10	0	Yes	--
175	10	0	Yes	80

MARTENSITE TRANSFORMATION

Quench Temperature Deg.Fahr.	Time in Quench	Temper Temperature Deg.Fahr.	Martensite Transformation %	Underbead Cracking	Rockwell Hardness 30 "N" Scale
400	10 Min.	850	20	No	76-1/2
375	10 Min.	850	40	No	72
325	10 Min.	850	60	No	70
275	10 Min.	850	70	No	69-1/2
225	10 Min.	850	80	No	69-1/2
175	10 Min.	850	90	No	70-1/2

specimens. Figure 8 presents the time-temperature-transformation characteristics diagrammatically and includes the underbead-cracking observation. Photographs of typical microstructure of the heat-affected zones observed during this test together with data indicating time at temperature and estimated per cent of transformation are shown in Figs. 9, 10, 11 and 12. Figure 13 is a photomicrograph showing underbead cracking typical of that encountered in this test.

DISCUSSION

The behavior of the nickel-chromium-molybdenum alloy steel (Type A) in the circular-groove weld test indicated that under ordinary production conditions; i.e., preheat and interpass temperatures of 200 to 300° F.; satisfactory deep-groove welds could not be deposited with the $^{3}/_{16}$-in. diameter Type 310 (25–20) electrodes when the restraint imposed approached the desired level. Even a preheat temperature of 500° F. with an uncontrolled interpass temperature failed to bring about any change in the test results. However, with a preheat temperature of 600° F. and a controlled interpass temperature of 600–700° F., it was possible to obtain satisfactory deep groove welds under the maximum restraint imposed by the test; namely, 4-in. diameter patch. At preheat and controlled interpass temperatures below 600° F. it was not possible to obtain satisfactory welds at the level of restraint established for nickel-chromium alloy steel (Type B); namely, 6-in. diameter patch.

When the cladding method was used, it was possible to obtain satisfactory welds at the 6-in. level of restraint using welding procedures comparable to that employed in the field. For the cladding operation, it was found that the preheat temperature could be reduced to 150° F. and for the deposition of the groove weld, the preheat temperature could be reduced to 70° F. and the interpass temperature maintained at less than 150° F. without encountering any difficulty in depositing satisfactory welds at the desired level of restraint. It is probable that this technique might have proved satisfactory for the deposition of groove welds at higher levels of restraint (smaller patch diameters). Because of the shortage of material, it was not possible to further investigate this welding procedure.

The study of the isothermal characteristics in the heat-affected zone of the Type A steel, developed upon deposition of single bead welds at various preheat temperatures, is of considerable interest. It had been considered that these characteristics were of influence in obtaining satisfactory weld deposits since it was indicated by comparison of test results that field activities were experiencing difficulty in obtaining satisfactory welds at preheat temperatures found suitable by the laboratory. However, it was not anticipated that underbead cracking would be encountered upon examination of the specimens used for this investigation. As indicated by Fig. 8, underbead cracking ap-

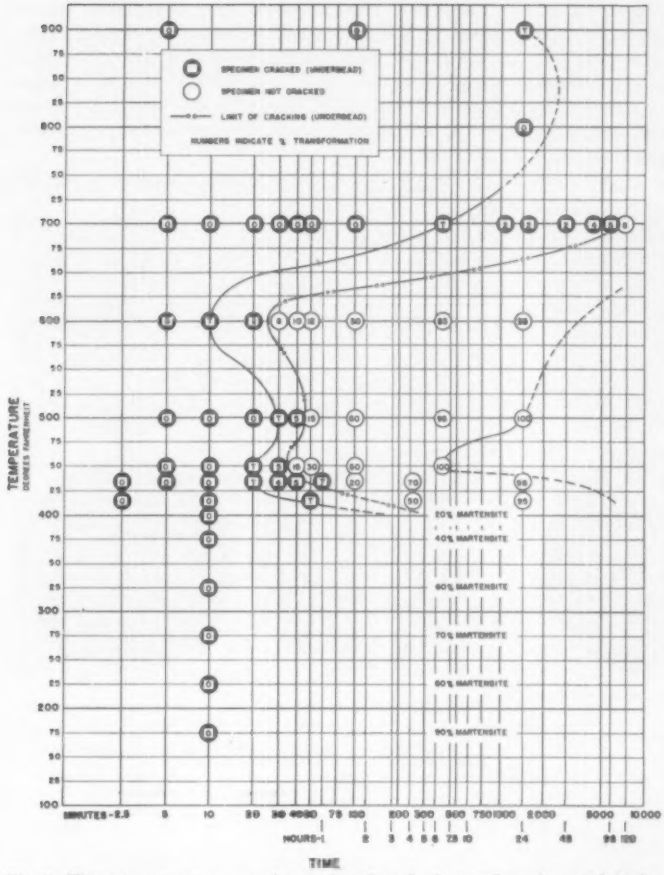

SPECIMEN CRACKED (UNDERBEAD)
SPECIMEN NOT CRACKED
LIMIT OF CRACKING (UNDERBEAD)
NUMBERS INDICATE % TRANSFORMATION
TEMPERATURE
20% MARTENSITE
40% MARTENSITE
60% MARTENSITE
70% MARTENSITE
80% MARTENSITE
90% MARTENSITE
MINUTES - 2.5 5 10 20 30 40 60 75 100 200 300 400 750 1000 2000 5000 10000
HOURS - 1 2 3 4 5 6 7.5 10 24 48 96 120
TIME

Fig. 8 Time-temperature-transformation chart for heat-affected zone of single-pass weld deposits

Nickel-chromium-molybdenum alloy steel Type A

pears to be a function of the bainite transformation and does not occur when the transformation has progressed beyond approximately 8% of bainite formed. It is also interesting to note that at 700° F. cracking was persistent after 96 hr. at that temperature. Furthermore, where specimens were quickly cooled without interruption to below the temperature at which martensite transformation begins and then tempered at 850° F. prior to cooling to 32° F. underbead cracks were not found.

Attention is invited to the fact that the underbead cracking observed occurred at very low levels of restraint in so far as that imposed by the weld bead is concerned. This would indicate the heat-affected zone of the material to be crack sensitive when subjected to thermal shock. The imposition of weld restraint in addition to thermal shock would increase the range of transformation product over which cracking would occur. Furthermore, it is to be pointed out that the weld beads were deposited using a so-called low-hydrogen type electrode capable of producing arc atmospheres low in hydrogen. Therefore, it is not believed that hydrogen absorption has been a factor in the observed underweld cracking. For, had hydrogen been involved, it would be difficult to explain why sufficient diffusion of gas had occurred in 40 minutes at 450° F. to prevent cracking; while, at 700° F., more than 96 hr. were required to obtain the same result.

Based upon these observations, it would appear that the isothermal characteristics of the Type A steel predict the welding procedures applicable to that material. Referring to Table 3, it was not possible to obtain satisfactory restrained deep groove welds at preheat and interpass temperatures of less than 600° F. In these tests, the preheat temperature of the assembly was maintained after completion of the weld until the temperature throughout the plate reached equilibrium. This was accomplished by maintaining the outer portions of the plate surrounding the weld at the preheat temperature for 1 hr. after completion, after which the assembly was allowed to cool to room temperature. Again referring to Fig. 8, it is indicated that holding for 1 hr. at 600° F. would permit considerable transformation product to be formed before the assembly had cooled to room temperature. At preheat temperatures less than 600° F. but greater than 400° F., 1 hr. time does not appear to be sufficient to develop transformation product much in excess of the minimum to prevent cracking. At 400° F. and below, it would appear that the restraint imposed by the joint was sufficient to develop stresses exceeding the fracture stress of the heat-affected zone. This is indicated in Table 3 where satisfactory welds were obtained in the 7 in. diameter patch using a preheat of 200° F. and an interpass temperature of 200–300° F.

It has been the general assumption that the use of preheat will effectively reduce the cooling rate of the weld deposit by changing the rate of heat dissipation throughout the assembly. Consequently, the cooling rate should be inversely proportional to the preheat temperature and the higher the preheat temperature, the slower should be the cooling rate. Under these conditions it would appear that using a preheat temperature of 500° F., the cooling rate of the assembly would be sufficiently slow to cause an isothermal transformation of sufficient magnitude to prevent cracking without the

need for maintaining the preheat temperature for an extended period of time after completion of the weld. Since weld assemblies prepared at 500° F. preheat, even when held for 1 hr. at that temperature after completion of the weld, exhibited cracking in the heat-affected zone; it was the opinion that either the data presented in Fig. 8 were not representative of conditions developed in the weldments or that the function of preheat was not fully understood. Therefore, it was considered necessary to investigate the influence of preheat upon the cooling rate of the heat-affected zone in order to determine the relationship of the isothermal characteristics to the difficulties encountered in obtaining satisfactory restrained deep groove welds.

The influence of preheat upon the cooling rate was in-

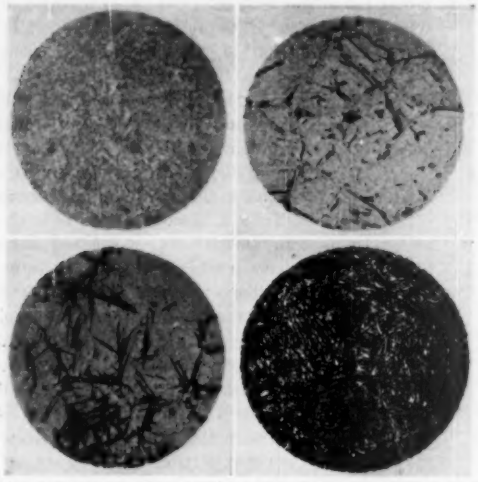


Fig. 9 Temperature 435° F., time-temperature-transformation characteristics

Heat-affected zone of single-pass weld deposits, magnification 200 ×. Nickel-chromium-molybdenum alloy steel Type A

10 Min.	0%
20 Min.	Trace
100 Min.	7%
1440 Min.	90%

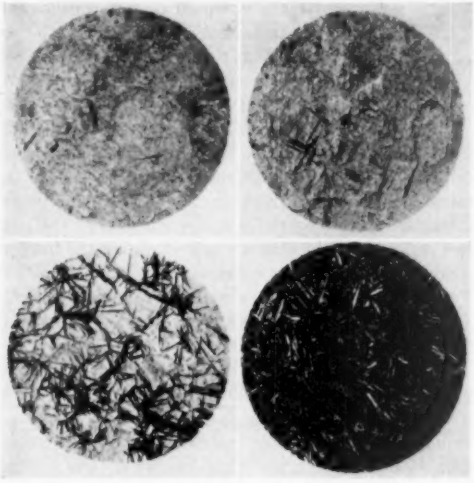


Fig. 10 Temperature 500° F., time-temperature-transformation characteristics

Heat-affected zone of single-pass weld deposits, magnification 200 ×. Nickel-chromium-molybdenum alloy steel Type A

20 Min.	0%
30 Min.	Trace
50 Min.	15%
1440 Min.	100%

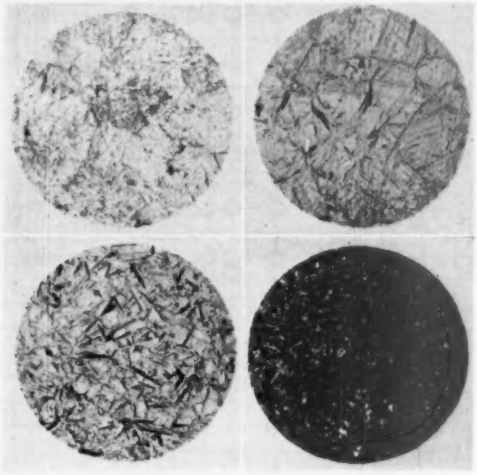


Fig. 11 Temperature 600° F., time-temperature-transformation characteristics

Heat-affected zone of single-pass weld deposits, magnification 200 ×. Nickel-chromium-molybdenum alloy steel Type A

5 Min.	0%
10 Min.	Trace
30 Min.	8%
1440 Min.	95%

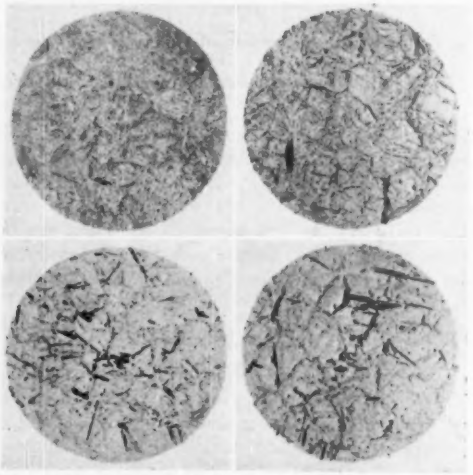


Fig. 12 Temperature 700° F., time-temperature-transformation characteristics

Heat-affected zone of single-pass weld deposits, magnification 200 ×. Nickel-chromium-molybdenum alloy steel Type A

100 Min.	0%
400 Min.	Trace
5760 Min.	5%
7200 Min.	8%

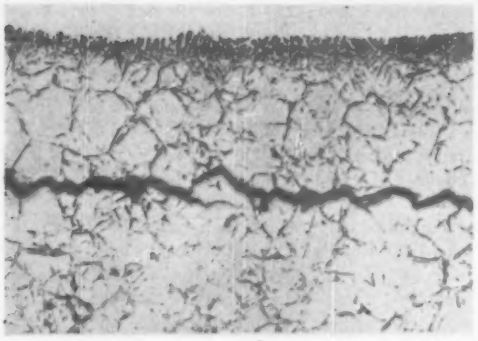


Fig. 13 Representative underbead crack in heat-affected zone, magnification 200 ×

Time-temperature-transformation characteristics, temp. 435° F., 40 min. Nickel-chromium-molybdenum alloy steel Type A

vestigated using 40-lb. nickel-chromium alloy- (Type B) steel test plates 12 in. sq. After the specimen had been brought to and held at the desired preheat temperature until equalized, a 10-in. long weld bead was deposited along the center line using automatic arc-voltage controlled welding equipment. In the exact center of the plate on the face opposite to the weld, a chromel-alumel thermocouple had been inserted so as to intercept and be fused to the bead as the weld progressed over the point of insertion. The temperature of the assembly was recorded using a General Electric Co. Photo Electric Millivolt Meter having a chart speed of 36 in. per minute and a full scale response of 0.2 sec. Tests were run at preheat temperatures of 70, 150, 300, 400 and 500° F. In addition, a circular patch test assembly was also prepared to investigate the cooling rate of the heat-affected zone in the fourth quadrant using similar means for recording temperatures. The circular patch test assembly consisted of a 40-lb. nickel-chromium alloy-steel (Type B) sample 24 in. sq. into which a 6-in. diameter patch was welded manually using a preheat temperature of 150° F. The exact details concerning the preparation of these test assemblies, together with the results obtained, are presented in Figs. 14 and 15 for the single weld beads and the circular patch assemblies, respectively.

The test data presented in Fig. 14 appear to indicate that the cooling rate of the heat-affected zone occurs in two distinct stages. The first stage appears to represent the quenching effect of the base plate and the second stage the rate of heat dissipation by radiation from the surface to the atmosphere. In the first stage, the rate of cooling is but slightly affected by change in preheat temperature. The average cooling rate from 1 to 11 sec. approximated 98° F. per second for the lowest preheat and 88° F. per second for the highest preheat.

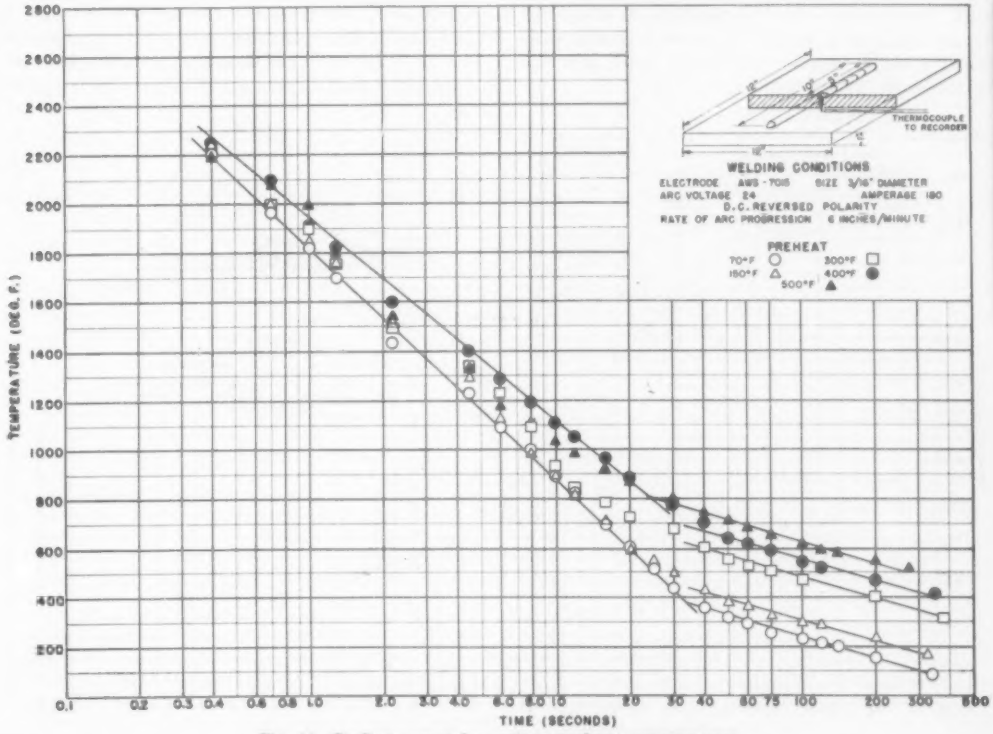


Fig. 14 Cooling curves for various preheat temperatures

Heat-affected zone of single-pass welds, nickel-chromium alloy steel Type B

The second stage of the cooling rates is also of particular interest in that the rate between 50 and 250 sec. approximates 1° F. per second regardless of preheat temperature. The only major differences to be noted between the various preheats is the approximate temperature at which the quenching effect of the plate becomes secondary to the heat loss by radiation in effecting the cooling rate. This change occurs at approximately 800, 700, 600, 425 and 375°F. for preheat temperatures 500, 400, 300, 150 and 70° F., respectively.

The data presented in Fig. 15 concerned with the cooling rate of the heat-affected zone of the circular patch test assembly show relatively the same characteristics as those of the single weld bead deposits. The first stage of the cooling rate representing the quenching effect of the plate shows an approximate rate of 95° F. per second between 2 and 12 sec. The second stage of the cooling rate, representing heat radiation to the atmosphere, shows a rate of 0.5° F. per second between 50 and 250 sec. The temperature at which the change from the first to second stage takes place is approximately 800° F.

A comparison of the results obtained for the circular patch assembly with those obtained for the single weld bead deposited at 150° F. preheat indicate comparable cooling rates in the first stage. However, in the second stage, the cooling rate of the circular patch assembly is approximately 50% as fast as that of the single weld bead. Furthermore, the temperature at which the change from first to second stage occurs was approximately twice as high for the circular patch as it was for the single weld bead; namely, 800° F. for the circular patch and 425° F. for the single weld bead.

The above noted differences between the patch assembly and the single weld-bead deposit are not readily understood. However, disregarding joint design and calculating heat imput as watt seconds per inch for the two welds; the heat imput for the circular patch assembly approximates 81,000 watt sec. per inch of weld while that of the single weld bead deposit approximates 43,000 watt sec. per inch. This would indicate that heat imput of the circular patch weld to be about twice that of the single weld bead. Since, except for joint design and size of plate, this is the only difference between the two assemblies, it may be assumed that heat imput like preheat has no appreciable effect on the quench cooling rate but has a sizable effect on the temperature at which the change from the first to second cooling stage takes place. In addition, the change in heat imput appears to influence the cooling rate during the second stage which is to be expected in view of the influence on the temperature at which the change from first to second stages takes place.

Though the cooling-rate data were obtained for the nickel-chromium alloy steel (Type B) only, it is believed that the results presented are comparable to those which would be obtained for the nickel-chromium-molybdenum alloy steel (Type A). Therefore, in view of the cooling data obtained under actual welding conditions, it is the opinion that the time-temperature-transformation characteristics of the heat-affected zone, as presented in Fig. 8, are associated with the problems involved in the welding of the nickel-chromium-molybdenum alloy steel (Type A). Though the isothermal

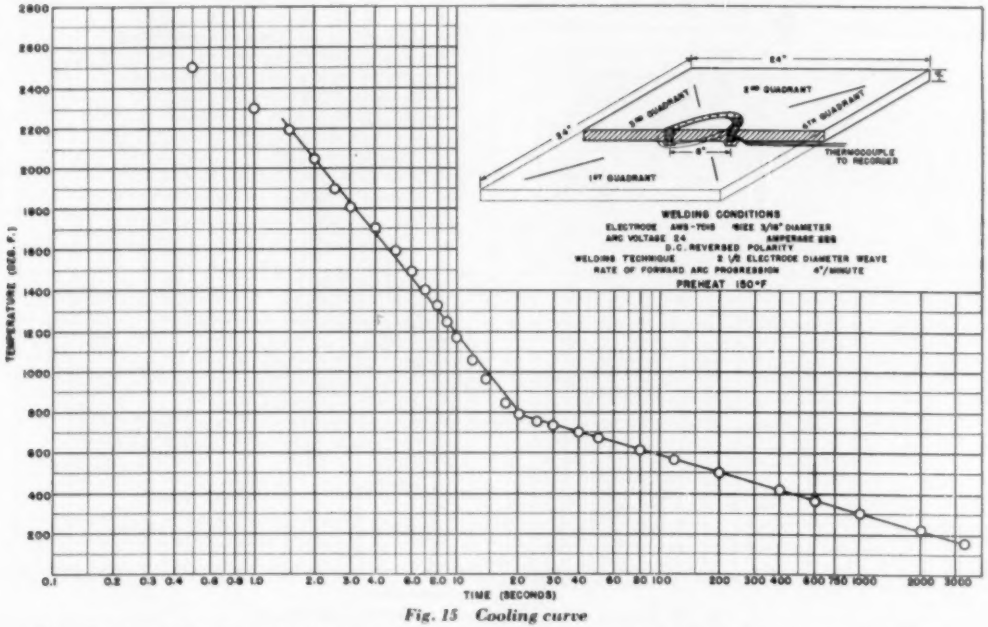


Fig. 15 Cooling curve

Heat-affected zone of circular-patch weld-test assembly. Fourth weld layer in fourth quadrant, nickel-chromium alloy steel Type B

characteristics at higher temperatures including the Ar′ Range (high-temperature region of rapid transformation or austenite-ferrite transformation) were not investigated, it is believed that the material is sufficiently sluggish even at these high temperatures to require a considerable interval of time to reach that point in the curve where transformation begins.

The study of the rates of cooling of the heat-affected zones of welds deposited at several preheat temperatures conducted as a part of this investigation should prove of particular interest in that the data presented herein are somewhat at variance with the generally accepted theory concerning the effect of preheat. When the study was first undertaken, Navy high-tensile steel plate was used. These data are presented in Fig. 16 and, as indicated, there appears to be three stages in the cooling cycle; an initial stage, intermediate stage and final stage. Since high-tensile steel requires excessively high cooling rate to develop full hardness, it is believed that the stages may be explained as follows:

The initial stage representing the quench effect of the base plate.

The intermediate stage representing effect of heat generated from the exothermic reaction caused by transformation from austenite to ferrite.

The final stage representing heat radiation from the plate.

Though no attempt is made to thoroughly discuss these data, the observations do indicate that preheat is effectual in regulating the cooling rate through the transformation temperature of nonair-hardening steels.

The End-Quench Hardenability Test results presented in Fig. 7 indicate that except for difference in maximum hardness obtained, minimum cooling rate to develop maximum hardness in the Type A steel is not appreciably less than that indicated for the Type B steel. This would appear to indicate that the isothermal characteristics developed in the heat-affected zone of weld deposits on the Type B steel though not similar,

Table 6—Preliminary Investigation Isothermal Characteristics

Heat-Affected Zone of Nickel-Chromium Alloy Steel Type B

Temperature level ° F.	*Time at temperatures, min.*	*Per cent transformation product formed*	*Underbead cracking*
900	0.5	0	Yes
	5.0	8	No
	10.0	20	No
600	0.5	Trace	Yes
	5.0	70	No
	10.0	90	No
	30.0	99	No
450	0.5	Trace	Yes
	5.0	100	No
	10.0	100	No
	30.0	100	No

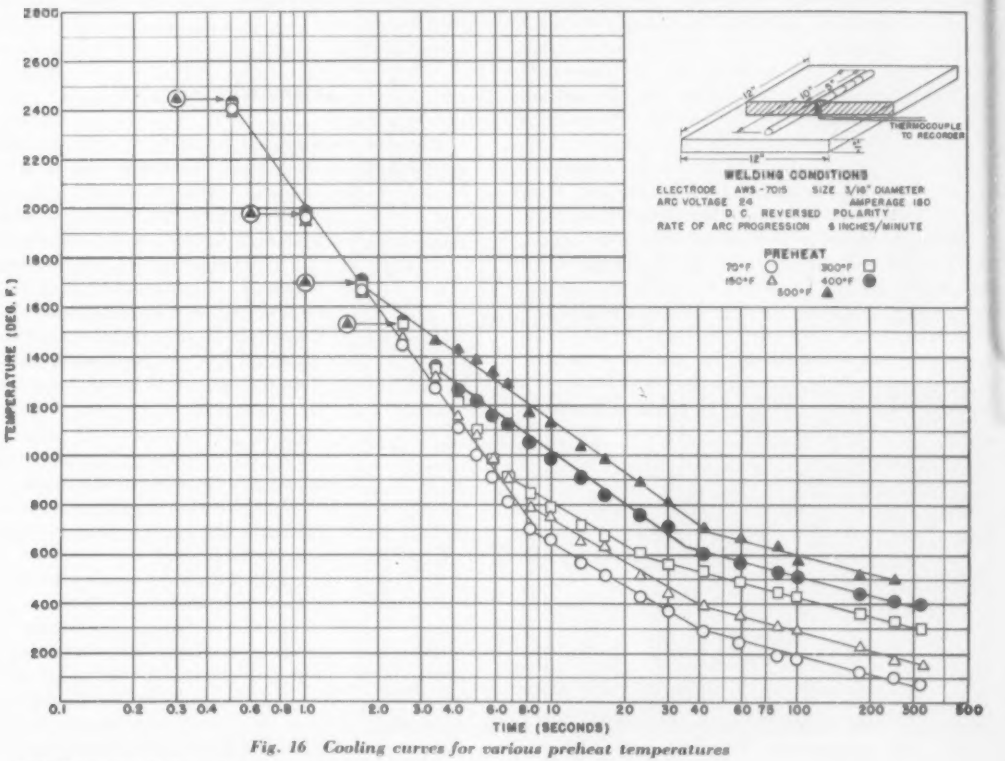


Fig. 16 Cooling curves for various preheat temperatures

Heat-affected zone of single-pass welds. High-tensile steel plate

would follow the same trend as those of the Type A steel. Using the same method as previously described for the isothermal investigation presented in Fig. 8, a preliminary investigation was made of the Type B steel and the results thereof presented below in Table 6.

The above preliminary test results indicate that the isothermal characteristics of the heat-affected zone of nickel-chromium alloy steel (Type B) follow the same pattern but that the time-temperature relationship is considerably different when compared with that of the Type A steel. It would appear that this time-temperature relationship is important for, as indicated in Table 6, transformation begins within 30 sec. at 600° F. Consequently, this would provide opportunity for the formation of such products in the heat-affected zone before reaching the temperature of martensite transformation.

SUMMARY OF FINDINGS

A summarization of the results of this investigation indicates that the nickel-chromium-molybdenum alloy steel is unsuitable for welded construction under conditions of high restraint and normal welding practice. The sluggishness of the material, preventing the formation of isothermal transformation products in the Ar′ region or region of austenite-ferrite transformation intensifies an unfavorable condition in the heat-affected zones of welds which are prone to cracking even under moderate restraint. The use of preheat has no appreciable effect in reducing the severity of base metal quench so that the cooling rate of the heat-affected zone would be sufficiently slow to permit the formation of any high-temperature transformation products. Likewise, preheat had insufficient effect on the cooling rate established by heat radiation from the surfaces of the assembly to permit the occurrence of isothermal transformation products in the heat-affected zone prior to reaching the temperature of martensite formation. It does appear that by regulation of preheat and interpass temperatures to within the range of from 450 to 600° F. (somewhat above the temperature of martensite transformation) and by maintaining the preheat temperature as a postheat temperature for a considerable period of time, 10–12 hr., after welding, sufficient austempering of the heat-affected zone should occur to permit completion of satisfactory welds under high levels of restraint. However, the use and maintenance of such high preheats over long periods of time is considered impracticable in so far as heavy construction is concerned.

In view of the ineffectiveness of applicable preheat in obtaining satisfactory welds under high restraint, there appears but one alternative, and that is to keep the restraint, from the weld during the time the heat-affected zone is in that condition conducive to cracking. This is accomplished by the cladding method. In this method the scarfs of the joint are clad with weld metal using moderate preheat. The joint is then assembled and by welding on the cladded surfaces, sufficient heat is developed in the heat-affected zone of the base metal under the clad, to temper it into a condition where it will stand considerable strain without failure. As indicated herein, satisfactory welds may be deposited under high levels of restraint without using excessively high preheats.

Underweld cracking, occurring in air hardening alloy steels when welded with low-hydrogen type electrodes such as Type 310 (25–20), is associated with the isothermal characteristics of the base metal. Where restraint is not a factor, it appears that 8% bainite transformation is necessary to avoid cracking. As restraint is increased, it is the opinion that the per cent of transformation product necessary to prevent cracking likewise increases.

ACKNOWLEDGMENT

The author wishes to express his appreciation for the suggestions and enthusiastic encouragement received from J. E. McCambridge, Technical Head of the Industrial Test Laboratory, Philadelphia Naval Shipyard and C. A. Loomis, Bureau of Ships, Navy Department, Washington, D. C., in the persuance of this investigation. To C. T. Gayley, J. M. Schwartz, O. H. Wuetig and the other members of the Metals Branch of the Industrial Test Laboratory for their diligence in directing the various phases of the investigation, obtaining and correlating of the data presented herein, the author is grateful.

(*Continued from page 551-s*)

quiring Project Committees to meet at least once a year. If a Project Committee is inactive for a longer period than a year the necessity for its continuance should be considered.

REPORTS

The basic conception and philosophy of the Council is the achievement of a wide dissemination of knowledge secured by research and utilization of results in practice and by code committees. Therefore, early publication is indicated. Nevertheless, in some instances for financial, editorial or other reasons it may seem desirable to a Project Committee to circulate the results of findings of its research work among Committee members well in advance of publication.

It is often very helpful if Project Committees will review reports of research laboratories before publication. Sometimes members of Project Committees will wish to issue comments and discussions of the reports which can be included along with the publication of the report itself. In certain instances Project Committees may wish to issue their own interpretative reports either at the same, or at a later, date as a supplement to

(*Continued on page 576-s*)

Stresses Around a Spot Weld Under Static and Cyclic Loads

Measurement of stresses taken at the interface of spot welds under static and fatigue loads; mild steel, stainless steel and aluminum welds in untreated and hydrostatically improved condition

by Georges Welter

INTRODUCTION

IN CONNECTION with the results of the investigation of the stress pattern in thin spot-welded sheets, as published in THE WELDING JOURNAL, 1949 (September issue of the *Welding Research Supplement*), this type of research has now been completed. Some results about this additional investigation will be shown, as carried out recently at the Research and Strength of Materials Laboratory of École Polytechnique at Montreal. Especially the exact distribution of the stresses around the spot, as measured at the outside surface of the sheet, has been studied in more detail as a function of the applied static tension loads. As already mentioned in my last work, the fairly surprising fact has been revealed that most of the stresses measured around the spot put under tension loads are compression stresses; only in a smaller area located in the axis between the point of loading and the spot itself were stresses found indicating tension.

Besides that, a quite new type of measurements, taken at the interface of the spot welds, were made. Also a great number of fatigue tests of untreated and hydrostatically improved specimens of mild steel, stainless steel and 24ST Alclad alloy sheets have been carried out.

Dr. Georges Welter is Professor of Applied Mechanics, École Polytechnique, Montreal, Canada.

STRESS DISTRIBUTION AROUND THE SPOT

At Outside Surface of the Joint

For this investigation, strain gages of different effective lengths, that is 1/2, 1/4 and 1/8 in., have been placed

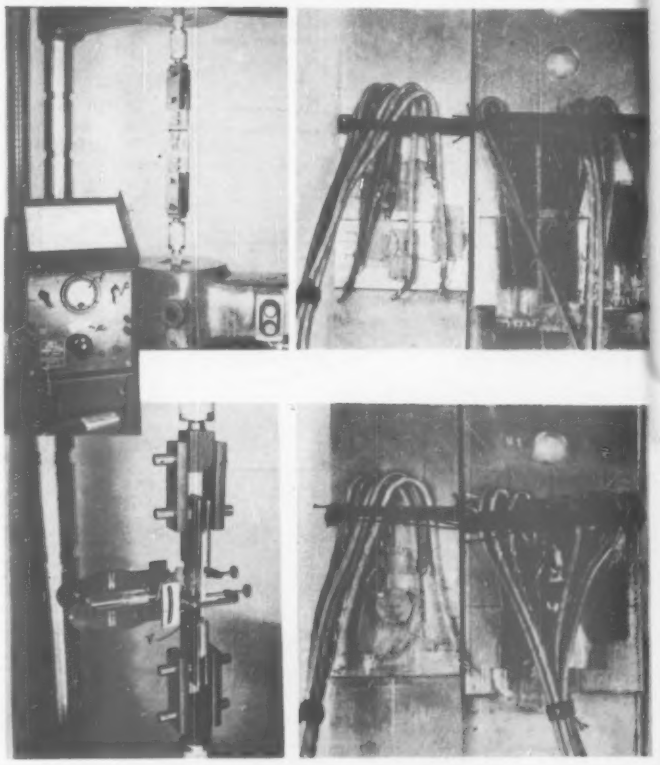


Fig. 1 Measurements in tensile test machine of spot-welded specimens with strain gages and Huggenberger extensometers

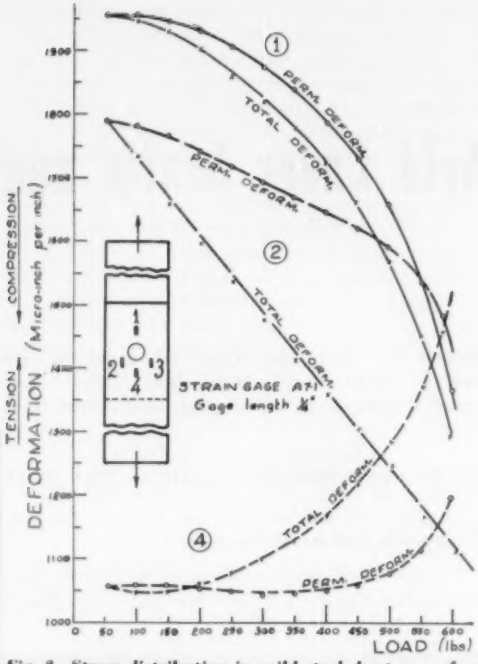


Fig. 2 Stress distribution in mild steel sheet on surface around the spot in function of the tension load

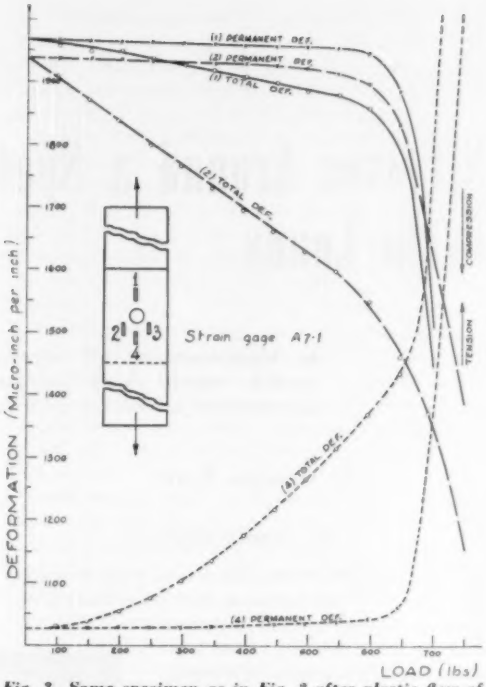


Fig. 3 Same specimen as in Fig. 2 after plastic flow of material under maximum load of 600 lb.

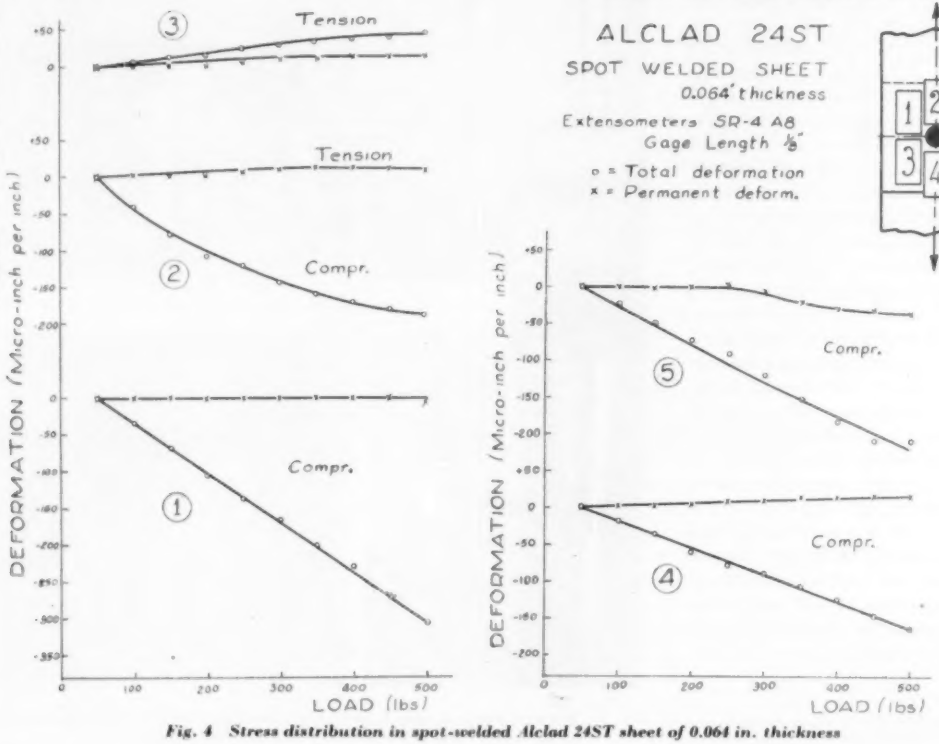


Fig. 4 Stress distribution in spot-welded Alclad 24ST sheet of 0.064 in. thickness

around the joint of the sheets and tested under tension loads. As shown in Fig. 1, mechanical extensometers of the Huggenberger type also were used. Some more details about the results of these measurements, representing fairly rough and preliminary results about this problem, are shown in Figs. 2 and 3. The first tests were carried out with welded mild steel sheets of 0.03 in. thickness and special strain gages of $^1/_4$ in. length placed around the spot, as shown schematically in the scheme of Fig. 2. The micro-deformations are indicated in inch per inch and reported in function of the applied load in steps of 100 lb. up to a maximum of 600 lb. According to these results, gage No. 1 indicated very pronounced compression stresses right from the beginning of the application of the tension load. The permanent deformations under zero load were nearly as great as the total deformations and increased very rapidly at a loading range of over 200 lb. Strain gage No. 2, located on the tension side of the spot, indicated also compression under increasing tension loads and the total deformations, represented by a straight line, were over twice the amount of the permanent deformations. Gage No. 3, placed symmetrically to No. 2, should indicate identical results; it was out of order and stresses could not be recorded. On the other hand, gage No. 4, situated on the tension side of the specimen, right in its axis, at a small distance of about $^1/_4$ in. from the border of the spot, indicated no strain at all under a load up to about 200 lb.; under higher loads, the total deformation in tension increased asymptotically and reached at 500 lb. about half of the amount of the deformations indicated by gages Nos. 1 and 2 working under compression. The permanent deformation in tension remained, at a load up to 450 lb., practically zero. This means that the elastic limit of the material had not yet been reached in this zone of the joint.

In order to find out if these indications of the strain gages were correct, these tensile tests were repeated with the same specimen after a maximum load of 600 lb. had been reached. As shown in Fig. 3 the strain was, as could be expected, this time, up to 600 lb., much smaller than in the preceding tests, except for the total deformation of gage No. 4 indicating tension. After the previous maximum load applied to this specimen had been surpassed, all gages indicated very rapidly increasing strain in the previously stated direction, that is Nos. 1 and 2 in compression and No. 4 in tension. Also the permanent deformation in tension of this gage indicated at this load the yielding of the material in zone No. 4.

These results seemed somewhat disturbing regarding the fact that the spot-welded mild steel sheets put under tension loads indicated at the outside surface around the spot mostly compression stresses, except for the gages on the tension side placed right in the axis of the specimen at some distance from the spot. Therefore, these results, obtained with mild steel specimens of 0.03 in. thickness, were checked with spot-welded Alclad 24ST

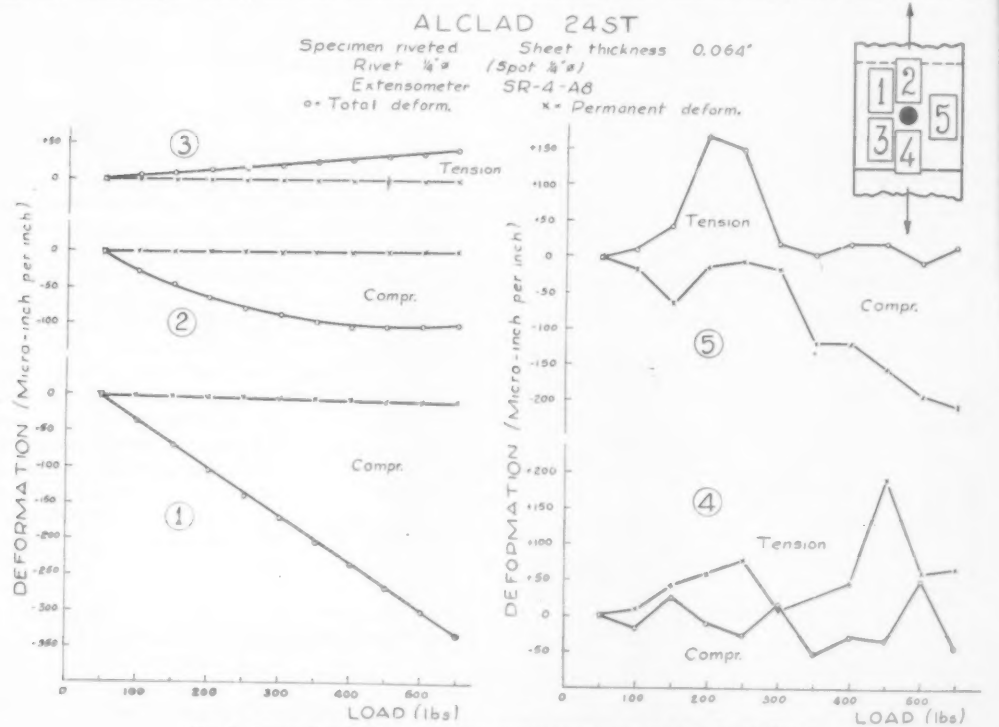


Fig. 5 Stress distribution in riveted Alclad 24ST sheet of 0.064 in. thickness

specimens of 0.064 in. sheet thickness. For these tests, smaller strain gages, having an effective length of only $^1/_8$ in., were placed as shown in Fig. 4, around the spot of about $^1/_4$ in. diameter, in the longitudinal axis; gages Nos. 2 and 4, as close as possible to the spot; in the transverse axis, gage No. 5 as well as on both sides Nos. 1 and 3. Here again, with the exception of gage No. 3, indicating very slight total and permanent tension stresses up to 500 lb., all other gages (Nos. 1, 2, 4 and 5) showed total deformations indicating very pronounced compression stresses while the permanent deformations, after unloading, were practically zero in all four cases.

Another Alclad specimen of the same thickness, having the same $^1/_8$-in. strain gage arrangement as in the preceding case, but instead of being spot welded had been riveted with a $^1/_8$-in. rivet, showed, according to Fig. 5, for gages Nos. 1 and 2, practically the same results indicated prevailingly by compression as for welded specimens. Gages Nos. 4 and 5 showed somewhat more irregular results, as for instance gage No. 4 showing variable permanent deformation in tension and total deformations prevailingly in compression; gage No. 5 was in tension for the total deformation and in compression regarding its permanent deformation under zero load. This may find some explanation by the fact that the rivet acts more by its head on the outside surface of the sheet while the spot, representing a rigid plug reaching through the thickness of both welded sheets, transmits the load through the volume of the sheet surrounding this plug.

In order to have some more information about these interesting stress variations over the surface of the joined Alclad 24ST sheets, specimens with double sheet thickness (0.128 in.) were tested, having mainly the same arrangement of the five strain gages as in the preceding tests. These specimens were spot welded and the strain gages of the type A-5 had an effective length of $^1/_2$ in. Here again, according to Fig. 6, the strain gages Nos. 1, 2 and 5 indicated for total as well as in a lesser degree for permanent deformation, compression stresses up to a load of 500 lb. Gages 3 and 4 remained practically uninfluenced showing only little compressive stresses for total and permanent deformations. These results are in fairly good agreement with those of the spot-welded Alclad 24ST sheet of 0.064 in. thickness (Fig. 4).

Similar results have been obtained with Alclad sheets of the same thickness of 0.128 in. by using, instead of gages of $^1/_2$ in. effective length, Huggenberger extensometers having also $^1/_2$ in. gage length. In all five zones, there were compression stresses prevailing in the total deformations under loads up to 500 lb. In Zone 3, there were, as in the preceding case, practically no

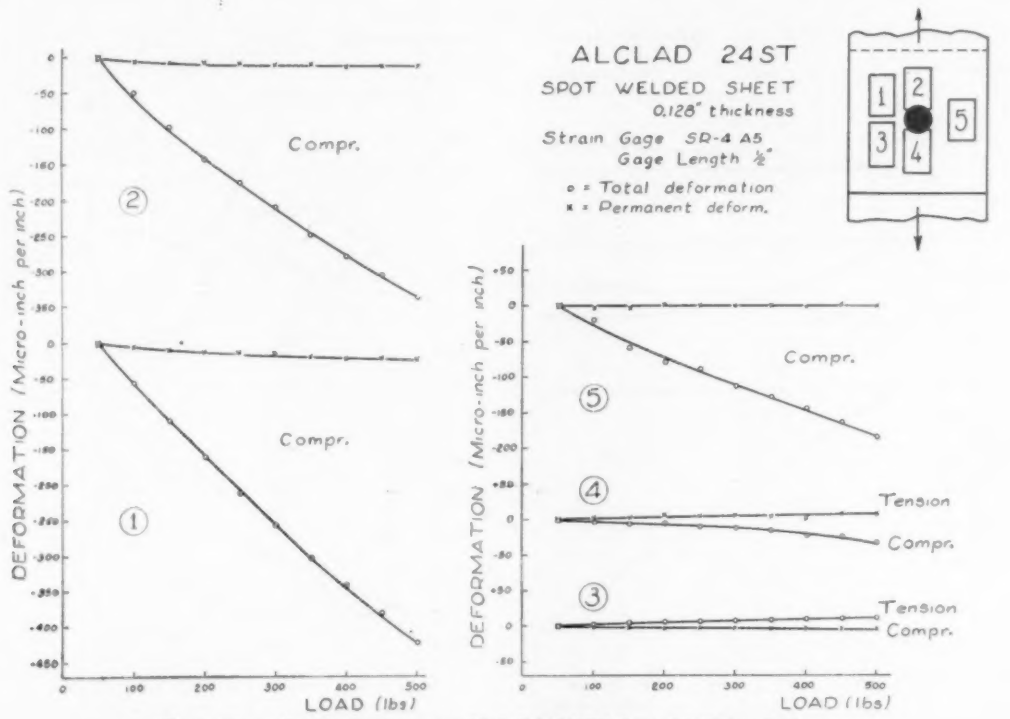


Fig. 6 Stress distribution in spot-welded Alclad 24ST sheet of 0.128 in. thickness

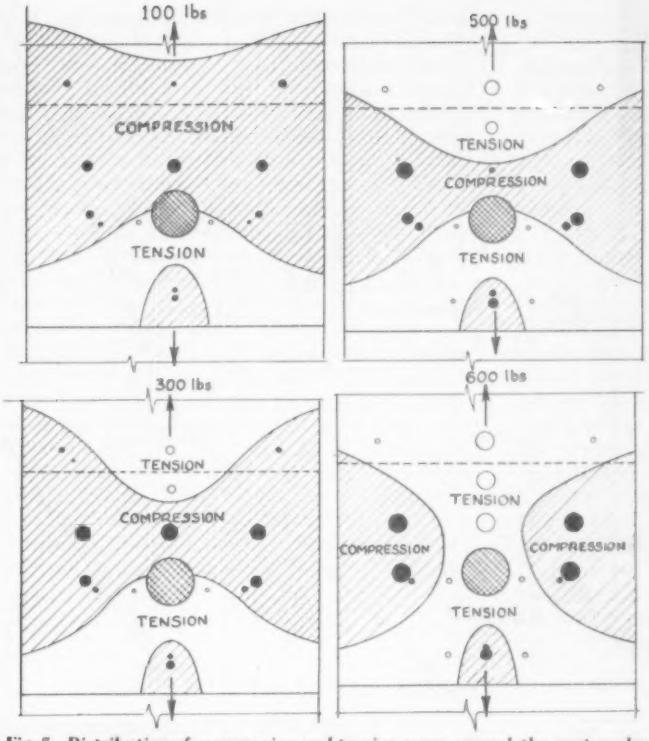


Fig. 7 Distribution of compression and tension areas around the spot under increasing loads (strain gages used: $^1/_4$ in. effective length)

deformations while Zone 4 showed only slight total deformation in compression.

Also, riveted Alclad specimens of this thickness were stress analyzed by strain gages of $^1/_2$ in. length under loads up to 400 lb. The load deformation curve showed, for the same zones, practically identical results, all zones around the spot being under compression.

In order to be quite sure of these strange results, showing prevailingly compression of the stresses around the spot, a completely identical test was carried out with an Alclad 24ST riveted specimen of 0.128 in. thickness using a rivet of $^1/_8$ in. diameter. Instead of electrical strain gages of $^1/_2$ in. length, a mechanical strain indicator of the same gage length was used. This instrument shows also that all zones 1 to 5, corresponding to the zones measured in the preceding riveted specimen as well as in the spot-welded specimens, compression took place in all zones except No. 3, indicating slight tension. Even an additional zone No. 6, situated at about $^1/_2$ in. from the upper border of the spot in the longitudinal axis of the specimen, showed, despite the distance of the measured zone from the joint, exclusively compression stresses under tension loads up to 350 lb.

By using the results of these various strain gage measurements carried out under increasing loads with various specimens, we can obtain a somewhat clearer picture in order to know what happens regarding the stress pattern taking place around the spots on the surfaces of the specimens. As shown by Fig. 7, the compression zone under a load of 100 lb. (upper left) is fairly large in spot-welded specimens and shows over the spot on the tension side a maximum of intensity just near the spot and is diminishing with increasing distance from the spot. Immediately under the spot, where a compression zone could be expected, there is a zone of very slight tension changing again into compression at some distance from the spot in the longitudinal axis of the sheet. Under a load of 300 lb. (lower left) this picture changes somewhat in so far as the compression zone becomes smaller in its central part without showing much changes in the rest of the stress pattern. At 500 lb. (upper right) this zone becomes still smaller in the center, as well as on both sides and at 600 lb. only the central part of the specimen becomes stressed in tension, leaving a compression zone on each side of the spot. The lower central part in compression remains practically uninfluenced by this fundamental change of the upper compression zone near the spot.

By using the results obtained with the Huggenberger extensometers, a fairly analogous stress distribution under a load of 400 lb., for instance, is obtained, as shown in Fig. 8. Altogether over 2500 measurements with various strain gages and welds have been carried out during this investigation.

Measurements Made at the Interface of the Joint

It is evident, however, that these interesting results

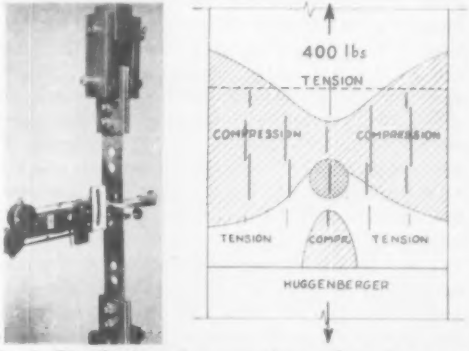


Fig. 8 Distribution of compression and tension areas around the spot under a load of 400 lb measured with Huggenberger extensometer

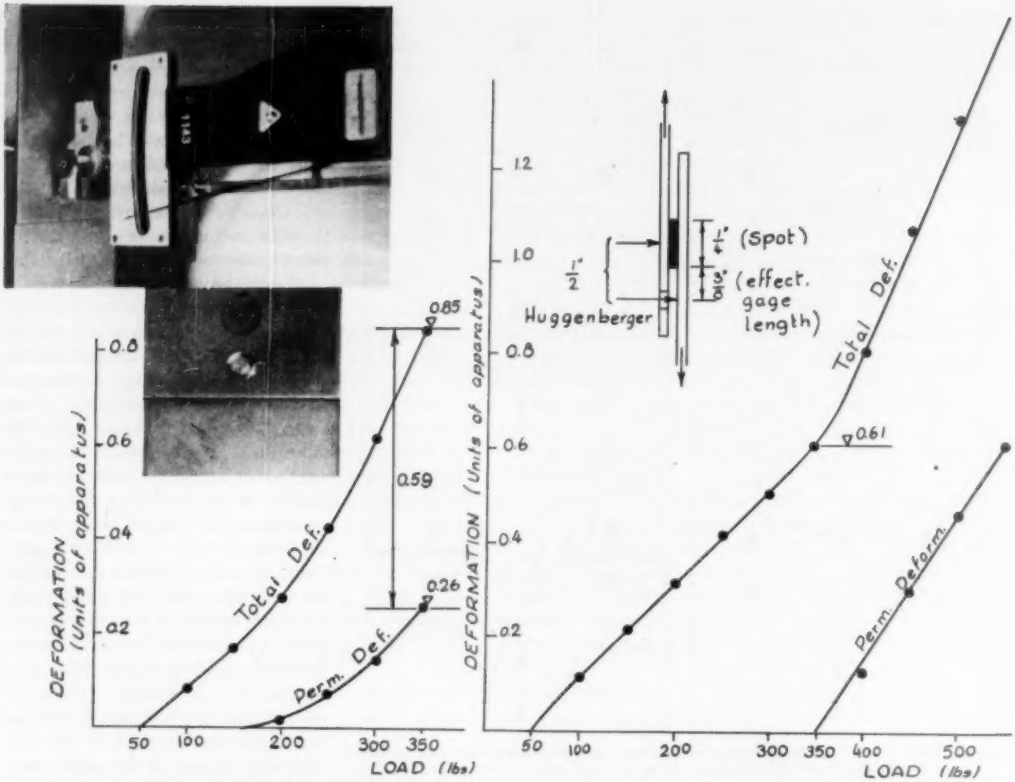


Fig. 9 Total and permanent deformations of sheets measured at inside surface near spot under increasing loads

obtained by measuring the total and permanent deformations on the surface of the specimen around the spot, do not tell yet the complete story of the stress distribution in these specimens. It is quite clear that simple tension, as applied on these specimens, cannot be converted into compression stresses, without finding a zone indicating major tensile stresses. It is logical that the tension loads, which have to be transmitted from one sheet to the other through the spot or the rivet, must produce somewhere zones showing very pronounced tensile stresses. It can be admitted that these tension stresses must take place mainly on the tension side of the spot in its longitudinal axis. Showing mostly, as we have seen, compression stresses on its outside surface, there must be pronounced tension stresses at the interface of the welded sheets. This statement will not be of great help if we do not succeed to support it by experimental results. Therefore, the next question was how can it be managed to measure these stresses at the interface of spot-welded sheets covering each other very tightly. By a simple procedure, we succeeded to measure very accurately the stresses taking place at the inside surfaces of the joints. By drilling a fairly small hole through the outside sheet in its compression zone, where it is without harmful influence on the stress distribution and without touching the material of the second sheet opposite to the hole, we can pass one leg of the Huggenberger extensometer through this hole; the other leg is applied on the outside surface of the rigid spot. By this means, we can now very easily measure

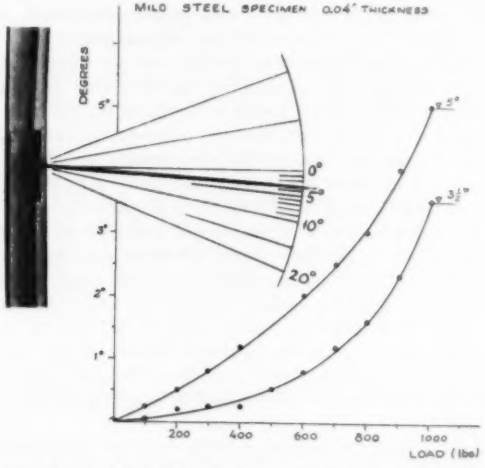


Fig. 10 Angle of elastic and permanent bending of the spot under increasing loads

what happens at the interface of the welded or riveted sheets. As can be seen in the sketch of Fig. 9 the mobile leg of the extensometer is applied through the hole on the inner surface of the sheet under tension. Under increasing loads we can very easily and accurately measure the total and permanent deformations taking place at the interface of the spot. The photograph on the left shows the instrument fixed on the spot welded specimen, having one leg passed through the hole of the sheet, while the other leg is fixed in the center of the rigid spot. The smallest gage length of the Huggenberger extensometer being $^1/_2$ in. and the spot having a diameter of about $^1/_4$ in., we can measure the permanent and total deformations under loads at the interface on the sheet under tension over a gage length of, as in this case, $^3/_8$ in., as indicated on the sketch on the right side of this figure. The second photograph shows the specimen as prepared for these tests, having below the spot a circular opening through the total thickness of the covering sheet. As first results of major interest, it was found that, contrarily to what has been measured on the surface of the specimen, all stresses located at the interface of the welded sheets, are exclusively tension stresses indicating a fairly pronounced value. The results* as measured under increasing loads up to 350 lb., showing quite regular curves of the total and permanent deformations in pure tension, are reproduced on the left side of this figure. Repeating the same measurements after having reached 350 lb. and starting again from zero load, we obtained the tension curves at the right end side of this figure. They indicate up to 350 lb. pure elastic total deformations under tension and no permanent deformation of the material could be measured. This proves that this instrument gives reliable results in tension over this short gage length of $^3/_8$ in. Similar results have been found for a still smaller gage length of $^1/_4$ in. In this case, the total and permanent deformations in pure tension are naturally smaller than those measured for greater gage lengths.

Curves of the same nature, indicating also pure tension stresses, have been found for a still smaller effective gage length of the extensometer of only $^1/_8$ and $^1/_{32}$ in. These results, are also in good agreement with the preceding ones; the deformation stresses under tension, total as well as permanent, and their maximum difference at 350 lb., diminished regularly with the decreasing gage length of the tension zone at the interface. By a thin steel foil of 0.001 in. thickness fixed with a small screw in the center of the spot, so that one leg of the Huggenberger could be placed at any point of this

* These tests have been carried out according to the indications of the author by G. Herrmann, Assistant Professor at the Research and Strength of Materials Laboratory.

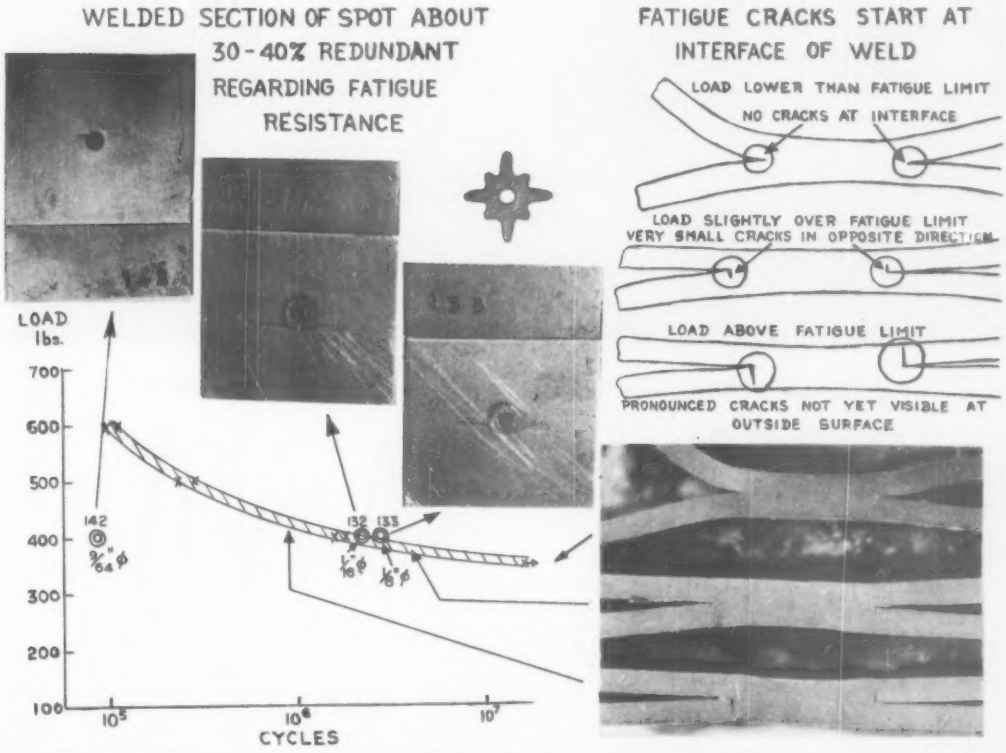


Fig. 11 Fatigue results of solid and hollow spots (left) and development of fatigue cracks at interface of weld (right)

rigid steel sheet, it was made possible to use the Huggenberger extensometers with a fixed gage length of minimum 1/2 in. to measure the tension stresses over a gage length of less than 1/4 in.

Angle of Bending of the Spot in Function of the Load

We went still further to explore the stresses in or around the spot by determining also the angle of bending in function of the increasing applied loads. The elastic and the plastic parts of this angle were measured and these results have been used for an approximate calculation of the stresses in the welded specimen. As shown in Fig. 10, this was fairly easily done by drilling a small hole through the center of the spot and fixing a fine needle of about 6 in. length, indicating over a scale divided in degrees the angle of bending of the rigid spot, suspended in the welded mild steel sheet of 0.04 in. thickness. The angles of total deformation in decimals of degrees under increasing loads up to 1000 lb. have been recorded and are reported upon in these curves. The single points indicate the fairly close relation existing between the angle of bending and the applied load. Under a load of 350 lb. an angle of total deformation of about one degree has been measured, showing a permanent deformation after the load has been released of about 1/4 of a degree. At a maximum load of 1000

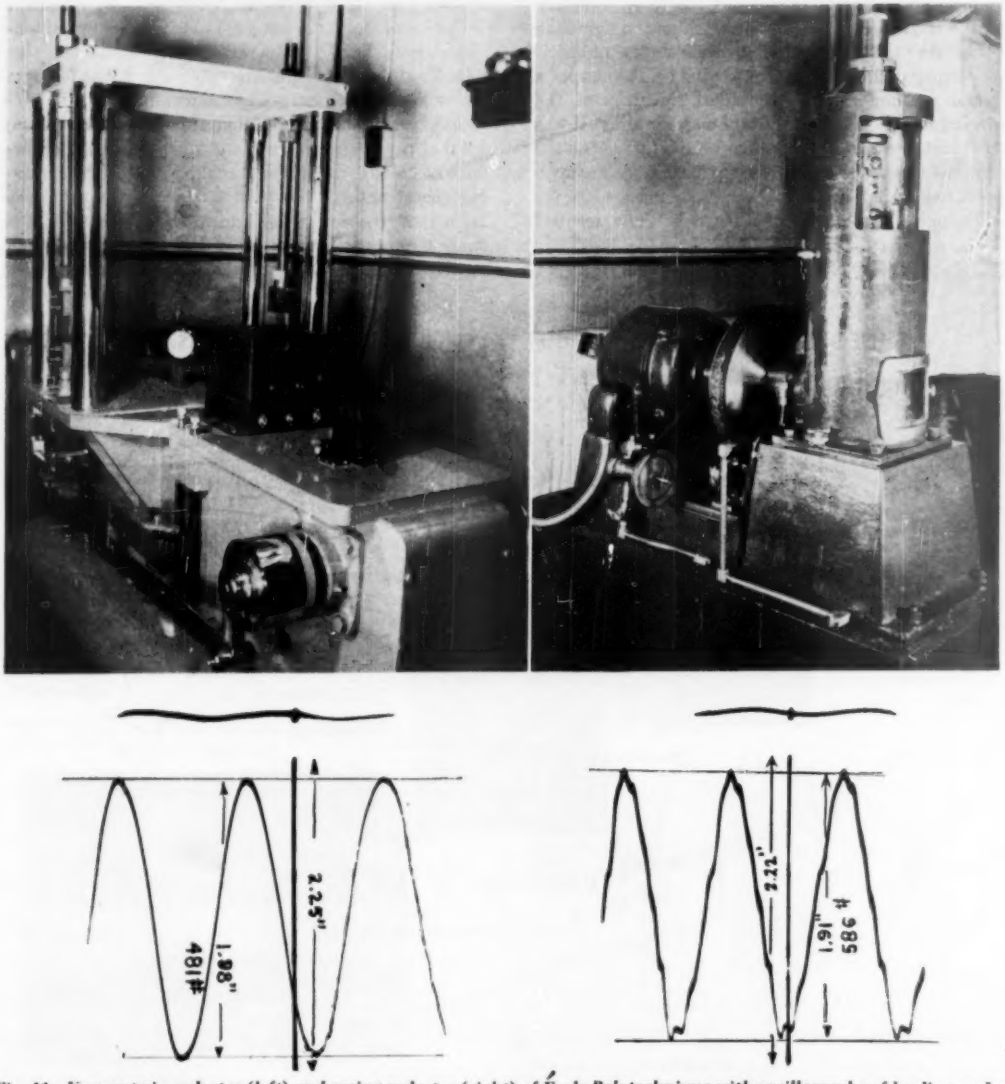


Fig. 12 Krouse twin pulsator (left) and spring pulsator (right) of École Polytechnique with oscillographs of loading cycles

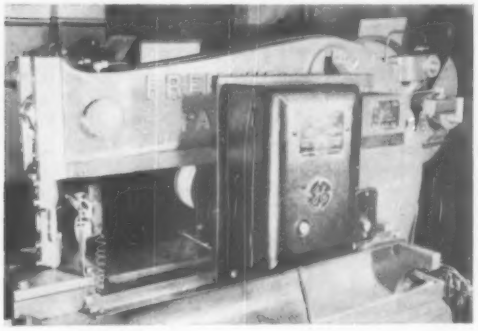
lb., the total bending of the spot was 5 degrees and the permanent one was $3^1/_2$ degrees.

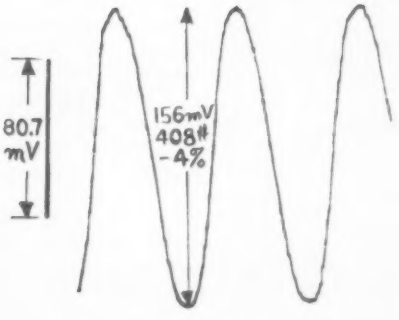
Fatigue Test Results

Regarding the fatigue resistance of spot welds, some investigations were made to find out if the weld is sufficiently resistant against fatigue loads. For this purpose the spots of a few mild steel specimens were perforated with drills of increasing diameter and these specimens were tested under cyclic loads on the Krouse twin pulsator. As shown in Fig. 11 (left) it can be seen that a hole of a certain diameter does not weaken the spot with regard to its fatigue resistance. So, for instance, a solid spot supports at a load of 400 lb. about 2,000,000 to 3,000,000 cycles before showing the characteristic crack around the spot. The same number of cycles was supported by spots with a hole of $^1/_8$ and $^1/_{16}$ in. (specimens Nos. 132 and 133).

Furthermore, we see in this figure, on the right-hand side how, under cyclic tension loads, the cracks develop in the sheet at the interface of the spot welds. By taking the fatigue specimens out of the pulsators before the fatigue crack developed at the outside surface and by cutting the specimen through the spot in its length axis, we could see, after severe plastic deformations of the sheet by bending near the spot, the beginning of the fatigue crack. So, for instance, at a repeated load which is about 20 to 30% higher than the fatigue limit, fairly heavy cracks developed at the interface of the weld in the two sheets in an opposite direction perpendicular to and starting at the inner sheet surface. These cracks develop at the beginning without showing any trace at the outside surface of the sheet. This can be seen at the right-hand side on the lower part of Fig. 11. A sheet put under still lower cyclic loads, which are only a few per cent higher than the endurance limit, shows much smaller cracks at the interface. These cracks develop only after a greater number of cyclic loads has been applied. This is indicated in the second sample on the right-hand side. Finally at the endurance limit itself, no crack at all develops at the interface of the sheets, as this is shown in the upper specimen at the right. After the application of over 10,000,000 cycles on the welded sheet, no crack at all could be found in this sheet.

The fatigue machines on which these special tests have been carried out, are shown in Fig. 12. We see here on the left the standard Krouse twin pulsator with an oscillograph for checking dynamically the amount of the cyclic loads, and pulsator No. 2 on the right-hand side which is of our own design and construction. In Fig. 13 we see two more pulsators used for this type of cyclic tests as developed in this laboratory. Six speci-





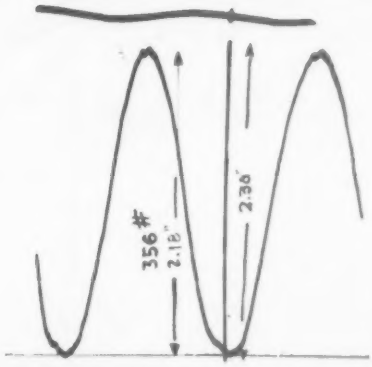


Fig. 13 Two special pulsators for fatigue tests of spot welds with oscillographs

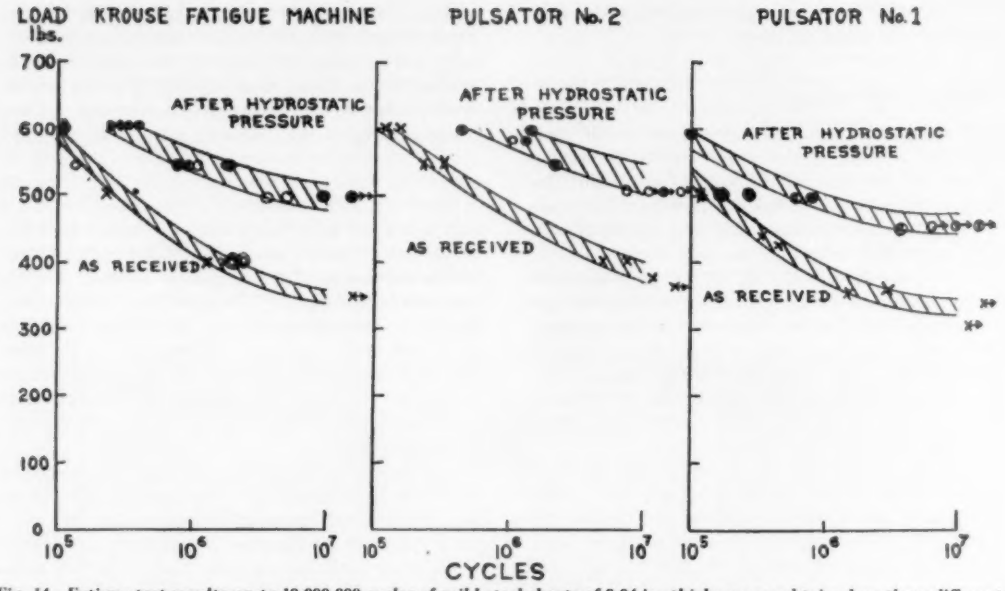


Fig. 14 Fatigue test results up to 10,000,000 cycles of mild steel sheets of 0.04 in. thickness, as obtained on three different pulsators; specimens as-received and after hydrostatic pressure

mens can be tested simultaneously in these machines and a fifth twin machine of a special type and design is under trial. These machines work day and night and they stop automatically when the specimen cracks.

In Fig. 14 can be seen the fatigue results obtained with mild steel specimens of 0.04 in. thickness on three of these machines. The specimens were tested in the as-received condition as well as after application of a hydrostatic pressure under loads up to 200,000 psi. An average improvement of the single spot of about 25 to 50% could be observed for this material.

The results obtained with spot-welded stainless steel sheets of 0.03 in. thickness are shown in Fig. 15. Here, too, an improvement of about the same amount as for

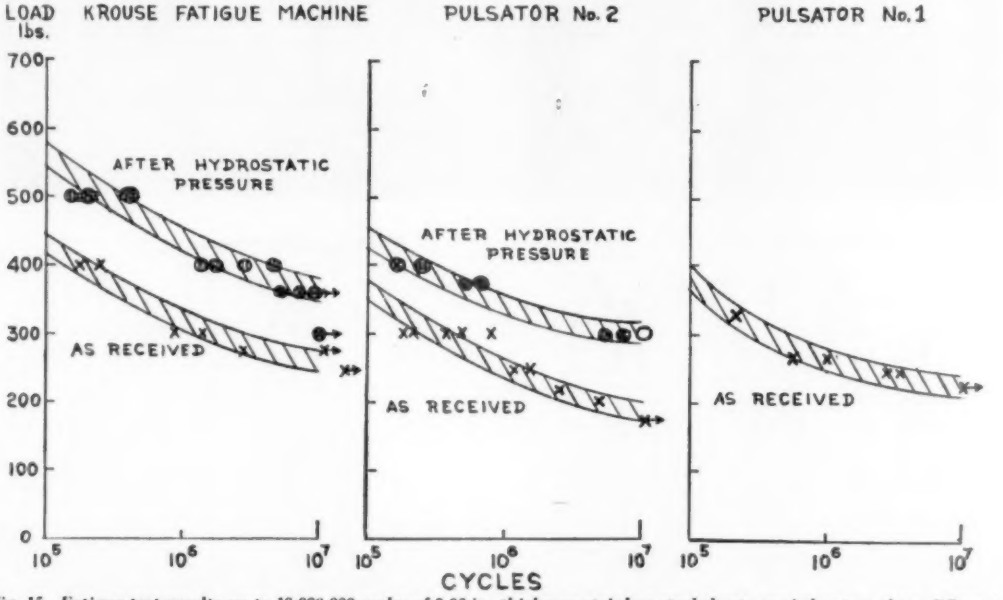


Fig. 15 Fatigue test results up to 10,000,000 cycles of 0.03 in. thickness stainless steel sheets carried out on three different pulsators

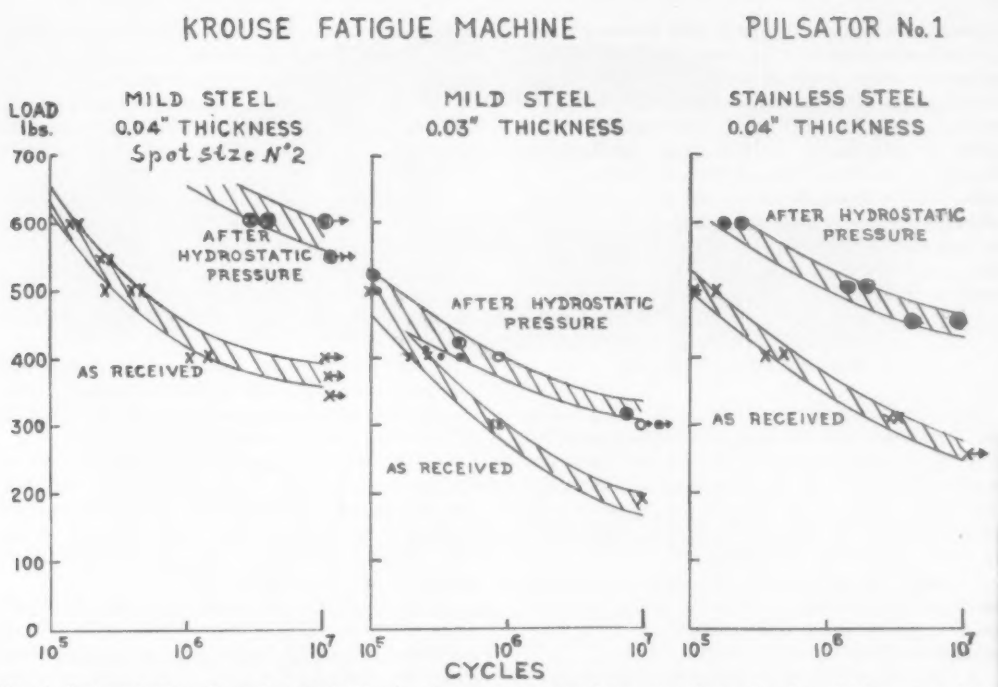


Fig. 16 Fatigue test results up to 10,000,000 cycles of mild steel and stainless steel sheets of various thicknesses and spot sizes

mild steel, that is 25 to 50%, has been recorded on three pulsators.

Similar results are shown in Fig. 16, representing fatigue tests of mild steel of 0.04 in. thickness using a spot of a greater diameter (spot size No. 2), as well as mild steel specimens of 0.03 in. thickness, both tested on the Krouse fatigue machine. Stainless steel of 0.04 in. thickness has been tested on pulsator No. 1 and is represented on the right side of this figure. For a final evaluation of the improvement of mechanically treated and untreated specimens, the S-N curves have to be continued to a higher number of cycles of at least 50 to 100 millions.

Fatigue tests with spot-welded 24ST Alclad sheets are represented in Fig. 17. The first results obtained show that the improvement by hydrostatic pressure is more effective with aluminum alloy specimens; higher fatigue loads of the order of about 80 to 100% have been recorded for this material. These fatigue tests have also to be carried out under a greater number of cycles up to at least 100 million cycles.

Comparing the fatigue results of untreated specimens of this series at a number of cycles of 10,000,000 with those represented in Fig. 11 on page 18 of the fatigue tests published previously (June 1948, *Welding Journal Research Supplement*), it can be said that the fatigue limit of these specimens has been found to be about 30 to 35% higher, that is about 250 to 275 lb., compared to 200 lb. as indicated in Fig. 11. Contrary to the results of this investigation, which have been determined by a greater number of specimens (Fig. 17), the fatigue limit of the previous tests, that is 200 lb. per spot, was based on results of other investigators, obtained on the same type of specimens and the same material. The results of specimens treated under high hydrostatic pressure, using various shapes of rams, are not yet concluded; a fatigue limit of about 600 lb. has been preliminarily established. There seems to be, however, possibilities to raise this limit to about 10 to 15% higher values.

With these various test results, we have gained valuable indications on the stress distribution in the sheet around the spot, as well as at the interface of the spot. It can now be expected that the fatigue limit of these spot welds can be improved still more and a higher percentage of amelioration can be attained compared to

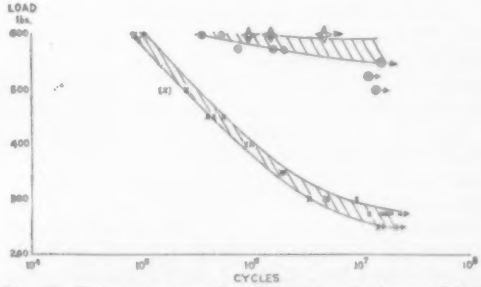


Fig. 17 Fatigue test results of 0.064 in. thickness Alclad 24ST sheets; specimens as-received and after hydrostatic treatment

untreated specimens. At present after having attained a better understanding of the stress distribution in and around the spots, it will be necessary to make further investigations into the improvement of the fatigue resistance of joints with more than one spot. The study of joints having multiple spots, distributed in various pattern over the sheet, are indeed very encouraging. After having carried out with success these supplementary investigations on multiple spot joints, the outlook seems bright to replace in the near future riveted light structures by spot-welded joints of higher fatigue resistance.

SUMMARY OF FINDINGS

According to the above test results, the following findings have been made during this investigation:

1. Spot-welded mild steel specimens put under tension loads up to 600 lb. indicate at the outside surface around the spot usually compression stresses; slight tension stresses were measured only at a small distance above the spot in the axis of the joint.

2. Also with spot-welded or riveted Alclad 24ST specimens, tested under identical conditions, the results showed mainly compression stresses on the surface around the spot.

3. By using, instead of electrical strain gages of various gage lengths, Huggenberger extensometers, these results could be confirmed.

4. Based on a greater number of results, a certain stress pattern taking place around the spot, under various loads up to 600 lb. could be established. This pattern seems to be independent of the measuring instruments used (electrical or mechanical gages).

5. Measurements made at the interface of the joint, instead of its outside surface, show that, due to bending of the sheet, exclusively tension stresses exist above the spot, having fairly pronounced values; permanent deformation starts already at loads of the order of 200 lb. in tension.

6. By measuring the angle of bending of the spot in function of the tension load, it has been found that a fairly close relation exists between this angle and the applied load; under a tension load of only 350 lb., a total bending deformation of about 1 degree and a permanent deformation of about $^1/_4$ degree have been found.

7. Under cyclic loads, the area of the spot in mild steel specimens is about 30 to 40% redundant; a much smaller area supports approximately the same number of cyclic loads before failure takes place.

8. Test results concerning the development of fatigue cracks under cyclic tension load show that these cracks start at the interface of the weld, due to repeated bending of the sheet in a zone close to the spot. These cracks develop a long time before they become visible at the outside surface of the sheet.

9. Fatigue results obtained with mild steel specimens of 0.04 in. thickness, obtained on three different pulsators, show that hydrostatically treated spots have a 25 to 50% higher fatigue limit than untreated joints. Similar results have been obtained with spot-welded 0.03 in. thick stainless steel sheets.

10. Hydrostatic compression of the spot is even more effective on 24ST Alclad aluminum alloy sheets; an improvement of 80 to 100% of their endurance limit is possible.

Rules of Procedure for Project Committees

(Continued from page 564-s)

the original report of the research laboratory.

Each Project Committee is encouraged at all times to issue its own interpretative report, which may be more readily used and accepted by Industry, or engage in the preparation of monographs which will include not only its own work but also closely allied research activities.

Each project financially supported by the Council should result in a report suitable for publication at least once a year. In other words, it is necessary actually to have a completed report or a progress report available for publication at the end of the year as conditional for expecting a renewal or continuance of a grant of funds. In exceptional cases this is not possible, but the burden of proof for these exceptions should be on the investigator.

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The actual cash expenditures of the Council represent approximately 25% of the total value of the research work published under its auspices. The other 75% represents investigations of committee members private industry and governmental departments, in work of direct interest to or closely allied with the work of the Council. The stimulation of this type of research work by Project Committees is exceedingly important.

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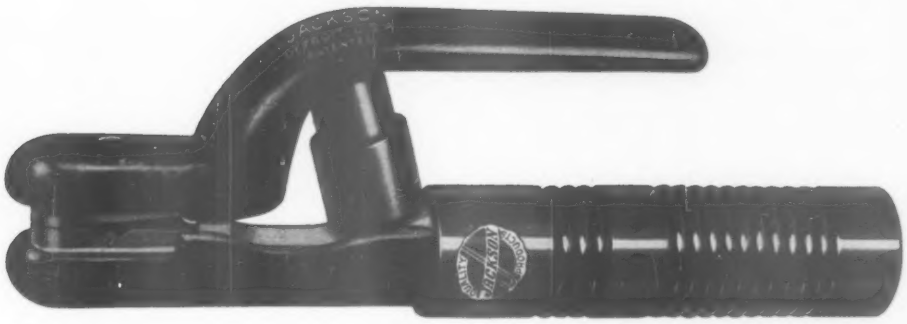
The Council requires that each Project Committee submit a budget on or before September 1st. Actually, this is a limiting date. It will be much more effective for financing and other purposes of these budgets are submitted on or before June 1st. The fiscal year of the Council begins October 1st.



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